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RESEARCH MEMORANDUM

ALTITUDE PERFORMANCE OF J71-A-2(600-D1) TURBOJET ENGINE

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NATIONAL ADVISORY COMMITTEE
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ALTITUDE PERFORMANCE OF J71-A-2(600-D1) TURBOJET ENGINE

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SUMMARY

The altitude performance of the J71-A-2(600-D1) turbojet engine, with afterburner inoperative and ejector shroud removed, was determined in an altitude test chamber over a range of engine speeds and exhaust-nozzle areas at Reynolds number indices from 0.1 to 0.7. These data are presented in the form of engine pumping characteristics, engine performance maps, and altitude performance at rated engine conditions.

When operating at rated engine speed, rated turbine-outlet temperature, and a flight Mach number of 0.8, the J71-A-2 turbojet engine experienced negligible loss in performance due to Reynolds number effects or decreased combustion efficiency up to an altitude of 35,000 feet. As altitude was increased from 35,000 to 57,500 feet, the net thrust was reduced to a value 5 percent below the value that could be obtained in the absence of Reynolds number effects. For the same altitude increase, the net thrust specific fuel consumption increased 3 percent because of Reynolds number effects and an additional 5.5 percent because of a decrease in combustion efficiency.

INTRODUCTION

As part of a complete investigation of the J71-A-2(600-D1) turbojet engine conducted in an altitude test chamber at the NACA Lewis laboratory, the steady-state altitude performance, with afterburner inoperative and ejector shroud removed, was obtained and is presented herein. The component performance of the J71-A-2(600-D1) turbojet engine is presented in reference 1. The effects of compressor interstage bleed and adjustable inlet guide vanes on compressor-stall characteristics are described in reference 2.

The J71-A-2 turbojet engine is equipped with compressor acceleration bleeds and two-position compressor-inlet guide vanes to avoid compressor stall at low engine speeds. During this investigation, data were taken over a range of engine speeds and exhaust-nozzle areas at Reynolds number indices from 0.1 to 0.7 with the inlet guide vanes open and the compressor acceleration bleeds closed (high-speed configuration). Some data were also obtained with the inlet guide vanes closed and compressor acceleration bleeds open (low-speed configuration).

Because standard operation at normal and military conditions is with the high-speed configuration, these data only are shown in graphical form. Data are presented in the form of engine pumping characteristics, engine performance maps at several flight conditions, and altitude performance at rated engine conditions. All the experimental data are included in tabular form.

APPARATUS

Engine

The J71-A-2(600-D1) turbojet engine has a bifurcated inlet, a 16-stage axial-flow compressor with acceleration bleeds and two-position inlet guide vanes, a cannular-type combustor with ten circular inner liners, a three-stage turbine, an afterburner, and an ejector-type exhaust nozzle. Both the primary and secondary nozzle are of the continuously variable iris type. The ejector was removed for this investigation.

The manufacturer's static sea-level rating of the J71-A-2(600-D1) engine, with afterburner inoperative, is 10,000 pounds of thrust with a specific fuel consumption of 0.955 pound per hour per pound of thrust at an engine speed of 6175 rpm, and a turbine-outlet temperature of 1240° F. At this condition, the air flow is 160 pounds per second, and the compressor-pressure ratio is about 9. The length of the engine with afterburner is 285 inches, the maximum height is 42 inches, and the maximum width is $42\frac{3}{8}$ inches. The frontal area based on compressor-tip diameter is 6.12 square feet. The dry weight of engine, afterburner, and accessories is about 4950 pounds.

The engine used for this investigation was number X-29 which differed from earlier engines of this model as follows: inlet-guide-vane settings, 0° (open) and +20° (closed) instead of -5° (open) and +15° (closed); compressor acceleration bleeds at the eighth stage instead of compressor discharge; and a minor stator change in the front compressor stages. The reference angles of 0° and +20° correspond to angles of +14° and +34° between the blade base line and the engine axis.

The engine control schedules the compressor acceleration bleeds to be open, the inlet guide vanes to be closed, and the exhaust nozzle to be open at actual engine speeds below 5300 rpm. At 5300 rpm, the compressor acceleration bleeds close, the inlet guide vanes open, and the exhaust nozzle begins to close according to a predetermined schedule with engine speed. The engine control schedule was interrupted during this investigation to allow independent control of the inlet guide vanes, compressor acceleration bleeds, and the exhaust nozzle.

The J71-A-2 turbojet engine had several minor air-flow bleeds. These were comprised of compressor acceleration bleed (with low-speed configuration, only) which was discharged overboard, mid-frame and aft-frame vent flows which were seal leakages and were discharged overboard, and turbine-cooling air bled from the outlet of the compressor and discharged between the turbine wheels where it reentered the main airstream. The compressor acceleration bleed flow varied from 7 to 4 percent of the engine-inlet air flow as engine speed varied from 3500 to 5300 rpm at a Reynolds number index of 0.4. The mid-frame and aft-frame vent flows amounted to 1.7, ±0.5 percent of the engine-inlet air flow except at low Reynolds number indices where these flows were as much as 2.5 percent. The turbine-cooling air flow was 1.3, ±0.5 percent of the engine-inlet air flow except at low Reynolds number indices where this flow was as much as 2.1 percent.

Installation

The altitude test chamber in which the engine was installed is a tank 10 feet in diameter and 60 feet long, divided into two compartments by a bulkhead. Air at pressures and temperatures giving the desired Reynolds number indices was supplied to the front compartment and was ducted into the engine through a bellmouth inlet and a venturi used to measure air flow. The rear compartment, which contained the engine and thrust measuring platform, was maintained at the desired altitude pressure. The engine installed in the altitude test chamber is shown in figure 1.

Instrumentation

Instrumentation for measuring pressures and temperatures was installed at various stations throughout the engine, as shown in figure 2. The table presented on the figure indicates the number and type of measurements obtained at each station. The total-pressure and -temperature probes at each station were located at the centers of equal annular area increments and the values averaged arithmetically. Instrumentation was also provided to measure the air flow at compressor acceleration bleeds, mid-frame and aft-frame vents, and turbine-cooling duct. The pressures were measured on manometers and photographically recorded; the temperatures were measured with iron-constantan or chromel-alumel thermocouples and recorded on self-balancing potentiometers. Exhaust-nozzle area was obtained from an indicator on the nozzle actuator. The calibration of this indicator with exhaust-nozzle area was made with the nozzle cold.

PROCEDURE

During the investigation of the J71-A-2 turbojet engine, performance 3999
data were taken at the following conditions:

Inlet guide vanes	Compressor acceleration bleeds	Reynolds number index	Exhaust nozzle	Nominal engine speed range, rpm
Open	Closed	0.2, .4, .7	Variable	4500 - 6175
Open	Closed	.1, .15, .2, .3, .4, .7	Fixed (near rated)	4500 - 6175
Closed	Open	.4	Fixed (near rated)	3500 - 6175
Closed	Open	.4	Open	3500 - 6175

Altitudes and flight Mach numbers associated with these Reynolds number indices may be determined from figure 3. The operating limit of the engine was determined by either a mechanical engine speed of 6175 rpm or a turbine-outlet temperature of 1240° F.

The fuel used throughout this investigation conformed to the specifications for MIL-F-5624A, grade JP-4, and had a lower heating value of 18,700 Btu per pound and a hydrogen-carbon ratio of 0.171.

Definitions of symbols, methods of calculation, and a sample calculation of performance from pumping characteristics are presented in appendices A, B, and C, respectively.

RESULTS AND DISCUSSION

Pumping Characteristics

The presentation of turbojet engine performance in terms of engine pressure ratio, engine temperature ratio, and air flow (pumping characteristics) provides a convenient and accurate basis for performance calculation. An advantage of this method is that engine performance can be calculated apart from the effects of inlet and outlet ducting, yet remain in terms that easily allow incorporation of any desired inlet- and outlet-duct losses. The pumping characteristics, combustion efficiency, and exhaust-ducting losses of the J71-A-2 turbojet engine are presented herein to aid performance calculation at any flight and engine condition within the range of Reynolds number indices and engine temperature ratios covered by this investigation. As previously indicated, a sample problem illustrating the use of curves presented in this section is given in appendix C.

In order to permit presentation of a large amount of pumping characteristic data with a minimum of figures, a complete pumping map is shown for one Reynolds number index only. Corrections to these pumping
3999 characteristics for other Reynolds number indices, over the range investigated, are then presented in succeeding figures. The pumping map in terms of engine total-pressure ratio, engine total temperature ratio, corrected air flow, and corrected engine speed is shown in figure 4 at a Reynolds number index of 0.4. Lines of cold actual exhaust-nozzle area are also indicated. The exhaust-nozzle-area lines are valid only when the exhaust nozzle is choked as shown by the limit lines at flight Mach numbers of 0.4 and 0.8. A Reynolds number index of 0.4 was selected for the pumping map because the widest range of corrected engine speed and of engine total-temperature ratio was obtained at this condition.

The effect of Reynolds number index on engine pumping characteristics is shown in figure 5 in terms of engine total-pressure ratio, air flow, and exhaust-nozzle-area corrections at a constant engine total-temperature ratio and corrected engine speed to the values read off the pumping map at a Reynolds number index of 0.4. The pumping characteristic corrections are valid for all engine temperature ratios within the range investigated. It should be noted that the engine total-pressure ratio does not include the exhaust system losses. These losses will be discussed later.

Engine total-pressure ratio and corrected air flow obtained by this method can be considered accurate within ±1 percent except at lower engine speeds where variations of corrected air flow were as high as ±3 percent. Exhaust-nozzle area calculated by this method is accurate within about ±3 percent. These accuracies apply only to engine number X-29 as differences between engines may be greater than this. Curves have been stopped at a Reynolds number index of 0.15 because insufficient data were taken at lower Reynolds number indices to retain the desired accuracy. At rated corrected engine speed, a decrease in Reynolds number index from 0.7 to 0.15 at a constant engine total-temperature ratio resulted in decreases in engine total-pressure ratio (fig. 5(a)) and corrected air flow (fig. 5(b)) of 8.5 and 4 percent, respectively. This would necessarily be accompanied by an increase in exhaust-nozzle-area (fig. 5(c)).

Engine fuel flow can be obtained easily and accurately by the use of the combustion efficiency and the engine temperature rise as shown by the sample calculation in appendix C. Combustion efficiency (fig. 6) has been correlated with the parameter $w_{a,1}T_9$ which is proportional to the more conventional parameter PT/V and is more convenient for calculation purposes. The combustion efficiency presented was obtained from data taken earlier in the J71-A-2 test program as the fuel flows measured during this portion of the present investigation were in error. All fuel flows presented herein were calculated by the given method.

As mentioned previously, the exhaust system losses are not included in the engine pumping map. In order to permit a calculation of thrust for the J71-A-2 turbojet engine, the tailpipe and exhaust-nozzle losses 3999 of this engine are presented in figures 7 and 8, respectively. The turbine-outlet gas flow parameter, which is used as the abcissa in figure 7, is a function of the turbine-outlet Mach number. The high tailpipe pressure loss at high values of turbine-outlet gas flow parameter are associated with high Mach numbers in the diffuser caused by excessive exhaust-nozzle area increase. This condition is definitely off design and was run only to obtain complete performance maps. At military and normal engine conditions the tailpipe pressure loss was 6 to 8 percent.

Thrust Correlation

As shown by reference 3, for an engine at nonafterburning conditions and with a choked exhaust nozzle, the jet thrust per unit of exhaust-nozzle area is equal to a constant times the exhaust-nozzle pressure-drop parameter, $1.26P_9 - p_0$. Figure 9 shows the scale jet thrust per unit cold actual exhaust-nozzle area against exhaust-nozzle pressure-drop parameter. This provides a simple method for obtaining jet thrust for the particular engine, tailpipe, and exhaust nozzle used in this investigation.

Control Temperature

The relation between the manufacturer's control-system thermocouple readings and values determined by a survey farther downstream in the tailpipe is shown in figure 10. The exhaust-gas total temperature was measured by fourteen thermocouples located on centers of equal annular areas at the exhaust-nozzle inlet. The twelve manufacturer's control-system thermocouples were located near midpassage approximately 14 inches downstream of the turbine and equally spaced circumferentially. The control temperature was in good agreement with the exhaust-gas total temperature, agreeing within 1.5 percent over the range investigated.

Engine Performance Maps

Engine performance has been calculated from pumping characteristics for altitudes of 20,000, 35,000, and 50,000 feet at a flight Mach number of 0.8, and for an altitude of 35,000 feet at a flight Mach number of 1.2 using NACA standard altitude conditions and 100-percent ram-pressure recovery. This information is presented in figure 11 in the form of engine performance maps. Data are shown on each map for engine speeds from 5200 to 6175 rpm and effective exhaust-nozzle areas from 2.6 to 4.4 square feet.

Minimum specific fuel consumption generally occurred between effective exhaust-nozzle areas of 2.6 and 3.0 square feet (rated area is about 2.9 sq ft) for all flight conditions investigated. As exhaust-nozzle area was increased beyond 3.0 square feet, specific fuel consumption increased rapidly because of a rapid increase in tailpipe pressure loss and a decrease in component efficiencies. Minimum specific fuel
3999 consumption varied only between 1.16 and 1.25 for altitudes from 20,000 to 50,000 feet at a flight Mach number of 0.8.

At engine conditions near rated, the thrust variation with engine speed is very small for a given exhaust-gas temperature, thereby eliminating any need for an extremely accurate control of engine speed. Furthermore, at the higher altitudes (figs. 11(b) and (d)) and rated exhaust-gas temperature, an improvement can be made in specific fuel consumption without any sacrifice in thrust by reducing engine speed below rated. In order to reach an optimum specific fuel consumption at some flight conditions, a reduction in effective exhaust-nozzle area beyond 2.6 square feet apparently would be required.

At any flight condition presented, the net thrust at rated engine speed can be reduced about 50 percent by increasing exhaust-nozzle area to the wide-open position. The customary increase in specific fuel consumption with increase in flight Mach number was experienced with this engine.

It should be noted that the exhaust-nozzle lines shown on these maps are hot effective exhaust-nozzle area. This area was used because of the difficulty in obtaining an accurate cold actual exhaust-nozzle area. This difficulty arose because the exhaust-nozzle actuator, to which the exhaust nozzle-area indicator was attached, was anchored at a point considerably ahead of the iris portion of the nozzle. Therefore, during engine operation, when the tailpipe became hot, the exhaust-nozzle skin expanded at a greater rate than the actuating mechanism and reduced the exhaust-nozzle area without changing the position of the exhaust-nozzle area indicator. However, data indicate the hot effective area was 0.95 ± 0.02 of the cold actual area.

Altitude Performance at Rated Engine Conditions

Altitude performance of the J71-A-2 turbojet engine is presented in terms of net thrust, fuel flow, and air flow at rated engine conditions (engine speed 6175 rpm and turbine-outlet temperature 1240° F) in figure 12. Altitude performance was calculated from pumping characteristics, assuming NACA standard atmosphere and 100-percent ram-pressure recovery, for altitudes from sea level to 55,000 feet and flight speeds from 0 to

800 knots, within limitations of the data. Although many current inlet ducts approach 100-percent ram-pressure recovery at subsonic and transonic conditions, the recoveries at supersonic conditions become much lower. For this reason, curves have been stopped at a flight speed of 800 knots. Performance at pressure recoveries other than 100 percent may be calculated at these or higher flight speeds by using the engine pumping characteristics presented herein. In accordance with the trends of figure 5, it was assumed there were no Reynolds number effects above a Reynolds number index of 0.7 for all data presented herein. 3999

At static sea-level rated conditions, the net thrust was 9950 pounds, the specific fuel consumption was 0.98 pounds per hour per pound of thrust, and the air flow was 164 pounds per second. At sea level, the rated net thrust was a minimum of 8800 pounds at a flight speed of about 300 knots. At a given flight speed, specific fuel consumption was a minimum at an altitude of 35,000 feet.

The altitude effect on the performance of the J71-A-2 turbojet engine at rated engine speed (6175 rpm) and rated turbine-outlet temperature (1240° F) is shown in figure 13 in terms of net thrust and specific fuel consumption for a flight Mach number of 0.8. Negligible loss in performance due to Reynolds number effects or decreased combustion efficiency was experienced up to an altitude of 35,000 feet. As altitude was increased from 35,000 to 57,500 feet, the net thrust was reduced to a value 5 percent below the value that could be obtained in the absence of Reynolds number effects. This loss was the result of decreases in corrected engine air flow and engine total-pressure ratio of 3 and 6 percent, respectively. For the same altitude increase, the net thrust specific fuel consumption increased 3 percent because of Reynolds number effects on compressor and turbine efficiency and an additional 5.5 percent because of a decrease in combustion efficiency.

CONCLUDING REMARKS

The J71-A-2 turbojet engine operating at rated engine speed and rated turbine-outlet temperature produced a static sea-level net thrust of 9950 pounds, a specific fuel consumption of 0.98 pound per hour per pound of thrust, and an air flow of 164 pounds per second. Maintaining rated engine conditions and increasing altitude, at a flight Mach number of 0.8, resulted in negligible loss in performance due to Reynolds number effects or decreased combustion efficiency up to an altitude of 35,000 feet. As altitude was increased from 35,000 to 57,500 feet, the net thrust was reduced to a value 5 percent below the value which could be obtained in the absence of Reynolds number effects. This loss was the result of decreases in corrected engine air flow and engine total-pressure ratio of 3 and 6 percent, respectively. For the same altitude increase, the net thrust specific fuel consumption increased 3 percent because of Reynolds number effects on compressor and turbine efficiency and an additional 5.5 percent because of a decrease in combustion efficiency.

At engine conditions near rated, the variation of net thrust with engine speed at a constant exhaust-gas temperature became very small, thereby eliminating any need for an extremely accurate control of engine speed. Furthermore, at the higher altitudes and rated exhaust-gas temperature, an improvement can be made in specific fuel consumption without any sacrifice in thrust by reducing engine speed below rated. At any flight condition presented, the net thrust at rated engine speed can be reduced about 50 percent by increasing exhaust-nozzle area to the wide-open position.

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National Advisory Committee for Aeronautics
Cleveland, Ohio, February 20, 1956

APPENDIX A

SYMBOLS

The following symbols are used in this report: 3999

A	area, sq ft
C	coefficient
F	thrust, lb
g	acceleration due to gravity, 32.17 ft/sec^2
H	enthalpy, Btu/lb
LHV	lower heating value, Btu/lb
M	Mach number
N	engine speed, rpm
P	total pressure, lb/sq ft abs
p	static pressure, lb/sq ft abs
R	gas constant, 53.3 ft-lb/(lb)($^{\circ}$R)
T	total temperature, $^{\circ}$R
t	static temperature, $^{\circ}$R
V	velocity, ft/sec or knots
w	flow rate, lb/sec or lb/hr
γ	ratio of specific heats
δ	ratio of total pressure to NACA standard sea-level static pressure
$\delta/\varphi\sqrt{\theta}$	Reynolds number index
η	efficiency
θ	ratio of total temperature to NACA standard sea-level static temperature
φ	ratio of absolute viscosity to viscosity of NACA standard atmosphere at sea level

Subscripts:

A	acceleration bleed
AV	aft-frame vent
a	air
b	combustor
c	compressor
d	discharge
e	effective
f	fuel
g	gas
i	inlet duct
j	jet
MV	mid-frame vent
n	net
s	scale
T	turbine cooling
v	velocity
0	free-stream conditions
1	venturi throat
2	compressor inlet
3	compressor outlet, combustor inlet
4	combustor outlet, turbine inlet
5	turbine outlet
9	exhaust-nozzle inlet
10	exhaust-nozzle throat

APPENDIX B

METHODS OF CALCULATION

Air Flow

The engine-inlet air flow $w_{a,1}$ was calculated from one-dimensional compressible-flow relations (ref. 4) using the effective area and the average pressures and temperatures at station 1. The effective area at station 1 was 3.959 square feet (A_1 = 3.983 sq ft, C_d = 0.994). Air bleeds and the addition of fuel resulted in the following mass flows at other stations: 3999

$$w_{a,3} = w_{a,1} - w_{a,A}$$

$$w_{g,4} = w_{a,3} - w_{a,T} - w_{a,MV} - w_{a,AV} + w_f/3600$$

$$w_{g,5} = w_{g,4} + w_{a,T}$$

$$w_{g,9} = w_{g,5}$$

Combustion Efficiency

The combustion efficiency is defined as the ratio of actual enthalpy rise to the theoretical enthalpy rise across the engine

$$\eta_b = \frac{\left. w_{a,1}H_a \right]_1^9 - \left. w_{a,A}H_a \right]_A^9 - \left. (w_{a,MV} + w_{a,AV})H_a \right]_3^9 + w_f \left[\frac{A_m + B}{m + 1}\right]_{T_f}^9}{(LHV)(w_f)}$$

where the lower heating value of the fuel LHV is 18,700 Btu/lb and the fuel temperature T_f was assumed to be 80° F. The term $(A_m + B)/(m + 1)$ is the difference between the enthalpy of carbon dioxide and water vapor in the burned mixture and the enthalpy of oxygen removed from the air by their formation (ref. 5).

Scale Jet Thrust

Scale jet thrust was determined from an algebraic summation of the forces acting on the engine. Because the bellmouth was attached to the engine-inlet duct instead of the front bulkhead, the force due to the momentum of the inlet air was not included.

$$F_{j,s} = F_B + A_i \Delta p_i$$

where F_B is the force due to the null-type balance, A_i is the area of the inlet duct at the bulkhead seal, and Δp_i is the difference in static pressure across the bulkhead.

Calculated Thrust

Jet thrust was calculated from gas flow and effective velocity.

$$F_j = \frac{w_{g,9}}{g} C_V V_e$$

The effective velocity, which includes the effect of excess pressure not converted to velocity for supercritical pressure ratios, was obtained from the effective velocity parameter of reference 4. The effective velocity parameter is a function of the exhaust-nozzle pressure ratio and the ratio of specific heats.

Net thrust was determined by subtracting the inlet momentum

$$F_n = F_j - \frac{w_{a,1}}{g} V_0$$

APPENDIX C

SAMPLE CALCULATION OF PERFORMANCE FROM PUMPING CHARACTERISTICS

In order to illustrate the method for obtaining engine performance from pumping characteristics, the following numerical example is presented:

The following flight and engine conditions were chosen: 3999

Altitude, ft.	35,000
Flight Mach number, M	0.8
Engine speed, N, rpm.	6175
Exhaust-gas temperature, T_9, $^{\circ}R$	1700

From this the following quantities are known:

$$p_0 = 498 \text{ lb/sq ft}$$

$$t_0 = 394^{\circ} \text{ R}$$

From these quantities, and assuming 100-percent ram-pressure recovery, the following parameters may be calculated:

$$V_0 = 779 \text{ ft/sec}$$

$$P_2 = 759 \text{ lb/sq ft}$$

$$T_1 = 444^{\circ} \text{ R}$$

$$\sqrt{\theta_1} = 0.925$$

$$\delta_2 = 0.359$$

$$\delta_2/\varphi_1\sqrt{\theta_1} = 0.439 \text{ (see fig. 3)}$$

$$N/\sqrt{\theta_1} = 6676 \text{ rpm}$$

$$T_9/T_1 = 3.83$$

From figure 4, the following may be obtained at a Reynolds number index of 0.4:

$$P_5/P_2 = 2.735$$

$$w_{a,1}\sqrt{\theta_1}/\delta_2 = 168.1 \text{ lb/sec}$$

Since the flight conditions selected is not at a Reynolds number index of 0.4, the following corrections to these parameters are necessary:

From figures 5(a) and (b):

$$\frac{P_5/P_2}{(P_5/P_2)_{\delta_2/\phi_1\sqrt{\theta_1}=0.4}} = 1.002$$

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$$\frac{w_{a,1}\sqrt{\theta_1}/\delta_2}{(w_{a,1}\sqrt{\theta_1}/\delta_2)_{\delta_2/\phi_1\sqrt{\theta_1}=0.4}} = 1.001$$

Multiplying by the corrections, the engine total-pressure ratio and corrected air flow can be obtained for the proper Reynolds number index.

$$P_5/P_2 = 2.740$$

$$w_{a,1}\sqrt{\theta_1}/\delta_2 = 168.3 \text{ lb/sec}$$

and

$$P_5 = 2080 \text{ lb/sq ft}$$

$$w_{a,1} = 65.3 \text{ lb/sec}$$

The mid-frame and aft-frame vent flows amount to 1.7 percent of the inlet air flow

$$\begin{aligned} w_{a,MV} + w_{a,AV} &= (0.017)(65.3) \\ &= 1.1 \text{ lb/sec} \end{aligned}$$

Since this air is lost overboard, the tailpipe air flow becomes:

$$\begin{aligned} w_{a,5} &= 65.3 - 1.1 \\ &= 64.2 \text{ lb/sec} \end{aligned}$$

To calculate fuel flow and thereby obtain gas flow, the following steps are required:

$$w_{a,1}T_9 = 111.0\times10^3$$

From figure 6,

$$\eta_b = 0.997$$

The engine temperature rise is

$$T_9 - T_1 = 1256^\circ \text{ R}$$

From figure 14 or reference 5,

$$(w_f/3600\ w_{a,5})_{ideal} = 0.01760$$

Dividing by combustion efficiency to obtain actual fuel-air ratio, 3999

$$w_f/3600\ w_{a,5} = 0.01765$$

and

$$w_f = 4079 \text{ lb/hr}$$

The gas flow then becomes:

$$w_{g,5} = 65.3 \text{ lb/sec}$$

To obtain exhaust-nozzle total pressure, it becomes necessary to determine the tailpipe pressure loss. To do this the following steps are necessary:

$$w_{g,5}\sqrt{T_9}/P_5 = 1.294$$

From figure 7,

$$(P_5 - P_9)/P_5 = 0.055$$

and

$$P_9 = 1966 \text{ lb/sq ft}$$

To obtain thrust, the following steps are necessary:

$$P_9/p_0 = 3.948$$

and the ratio of specific heats γ_9 for a fuel-air ratio of 0.01765 and a temperature of 1700° R is 1.33. From these parameters and figure 15 or reference 4, the effective velocity parameter can be found:

$$V_e/\sqrt{gRT_9} = 1.495$$

The effective velocity then becomes

$$V_e = 2555 \text{ ft/sec}$$

From figure 8, the effective velocity coefficient is

$$C_V = 0.960$$

and the jet thrust becomes

$$F_j = \frac{w_{g,5}}{g} C_V V_e$$

$$= 4979 \text{ lb}$$

Subtracting inlet momentum, the net thrust becomes

$$F_n = F_j - \frac{w_{a,1}}{g} V_0$$

$$= 3398 \text{ lb}$$

and the specific fuel consumption is

$$\frac{w_f}{F_n} = 1.200 \text{ (lb)/(hr)(lb thrust)}$$

cold actual exhaust nozzle area may be obtained by reading the area from figure 4 at a Reynolds number index of 0.4 and correcting to the proper Reynolds number index with figure 5(c), but a more accurate determination can be made by calculation as follows: The hot effective exhaust-nozzle area can be determined from the total-pressure parameter of figure 16 or reference 4.

$$P_9 A_{10,e} / w_{g,9} \sqrt{\frac{RT_9}{g}} = 1.485$$

and

$$A_{10,e} = 2.62 \text{ sq ft}$$

The ratio of hot effective to cold actual exhaust-nozzle area is 0.95. The cold actual exhaust-nozzle area then becomes

$$A_{10} = \frac{2.62}{0.95}$$

$$= 2.76 \text{ sq ft}$$

In calculating performance, if a choice of an exhaust-nozzle area is more desirable than an exhaust-gas temperature, the chosen exhaust-nozzle area must be corrected to the exhaust-nozzle area at a Reynolds number of 0.4 by the use of figure 5(c), then, the operating point can be located on figure 4 with the corrected engine speed and exhaust-nozzle area. The remaining calculations are identical to those presented herein.

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TABLE I. - INLET GUIDE VANES OPEN, COMPRESSOR ACCELERATION

(a) Variable exhaust-

Run	Reynolds number index, $\delta_2/\varphi_1\sqrt{\theta_1}$	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Cold actual exhaust-nozzle area, A_{10}, sq ft	Ambient static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Turbine-outlet total pressure, P_5, lb/sq ft abs	Exhaust-nozzle-inlet total pressure, P_9, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Exhaust-nozzle-inlet total temperature, T_9, °R
1	0.716	6060	6218	4.42	850	1417	2292	1684	493	1228
2	.710	6062	6214	3.79	841	1409	2544	2220	494	1293
3	.703	6058	6216	3.36	843	1392	2785	2550	493	1387
4	.713	6058	6216	3.10	838	1412	3099	2893	493	1515
5	.708	6058	6216	2.85	824	1402	3482	3282	493	1655
6	.714	5916	6058	4.42	850	1421	2224	1635	495	1187
7	.716	5920	6088	3.79	844	1420	2458	2130	494	1249
8	.715	5918	6066	3.30	840	1418	2789	2570	494	1365
9	.717	5900	6048	2.82	834	1423	3411	3214	494	1605
10	.714	5724	5861	4.42	835	1420	2093	1537	495	1132
11	.719	5719	5850	4.05	848	1434	2186	1805	498	1152
12	.718	5719	5850	3.54	844	1432	2417	2152	496	1225
13	.718	5717	5854	3.10	835	1428	2779	2587	495	1376
14	.713	5717	5854	2.82	849	1419	3171	2997	495	1549
15	.709	4909	5027	4.42	827	1410	1416	1136	495	851
16	.705	4908	5026	3.89	834	1403	1553	1337	495	895
17	.708	4904	5022	3.36	841	1408	1688	1536	495	956
18	.706	4898	5015	3.01	820	1404	1650	1719	495	1040
19	.715	4904	5032	3.01	846	1416	1858	1729	493	1044
20	.710	4904	5022	2.79	831	1413	2107	1982	495	1151
21	.397	6174	6847	4.42	388	639	1179	861	422	1277
22	.399	6173	6862	3.73	380	639	1288	1117	420	1345
23	.402	6173	6862	3.19	380	643	1362	1382	420	1487
24	.402	6171	6868	2.99	385	642	1500	1517	419	1599
25	.399	6173	6879	2.93	380	635	1571	1567	418	1647
26	.405	6173	6622	4.42	428	713	1257	912	451	1282
27	.403	6174	6616	3.54	429	711	1457	1306	452	1393
28	.405	6173	6637	3.25	421	708	1537	1413	449	1457
29	.402	6173	6622	3.19	422	707	1576	1463	451	1485
30	.407	6171	6642	2.99	424	710	1704	1598	448	1586
31	.408	6177	6648	2.90	428	712	1827	1724	448	1651
32	.404	5861	6515	4.42	384	646	1118	812	420	1152
33	.403	5863	6517	3.73	380	645	1216	1046	420	1211
34	.402	5863	6517	3.33	389	644	1337	1218	420	1290
35	.405	5859	6529	2.90	385	645	1564	1470	418	1468
36	.402	5869	6524	2.79	390	643	1580	1502	420	1559
37	.407	5626	6042	4.42	419	714	1128	822	450	1098
38	.406	5627	6043	4.26	424	712	1143	902	450	1108
39	.403	5627	6050	3.79	423	712	1218	1041	452	1150
40	.403	5624	6027	3.36	423	711	1331	1205	452	1222
41	.403	5627	6036	2.99	423	710	1509	1410	451	1365
42	.402	5624	6020	2.71	426	712	1726	1633	453	1516
43	.403	5242	5611	4.42	429	713	973	719	453	987
44	.399	5249	5619	4.26	427	707	989	776	453	995
45	.406	5247	5623	3.73	423	717	1075	915	452	1034
46	.406	5247	5641	3.36	425	711	1181	1070	449	1109
47	.399	5242	5593	3.13	421	713	1231	1134	456	1152
48	.403	5249	5631	3.01	423	710	1302	1211	451	1201
49	.403	5249	5631	2.68	420	710	1501	1421	451	1367
50	.411	4869	5235	4.42	428	719	820	630	449	859
51	.405	4869	5223	4.26	427	714	835	671	451	868
52	.405	4865	5219	3.73	425	714	888	759	451	904
53	.400	4875	5201	3.30	434	715	958	868	456	974
54	.404	4869	5206	3.27	426	718	961	870	454	968
55	.398	4867	5187	3.07	428	713	1005	928	457	1012
56	.408	4872	5238	2.93	429	714	1085	1009	449	1058
57	.401	4877	5214	2.79	425	713	1140	1067	454	1120
58	.400	4496	4792	4.42	424	716	655	544	457	752
59	.400	4492	4787	3.89	424	717	704	614	457	787
60	.398	4499	4789	3.42	424	714	764	695	458	837
61	.399	4495	4791	3.13	425	715	814	753	457	887
62	.400	4503	4799	2.85	426	716	900	844	457	972
63	.197	6174	6855	4.42	187	316	595	428	421	1342
64	.194	6173	6882	3.73	187	311	686	595	420	1414
65	.197	6173	6862	3.36	185	315	710	640	420	1502
66	.184	6176	6874	3.19	186	312	746	688	419	1570
67	.195	6174	6863	3.04	182	312	799	743	420	1677

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BLEEDS CLOSED (HIGH-SPEED CONFIGURATION)

nozzle area.

Manufacturer's control-system thermocouple readings, °R	Engine total-pressure ratio, P_5/P_2	Engine and tailpipe total-pressure ratio, P_9/P_2	Engine total-temperature ratio, T_9/T_1	Engine-inlet air flow, $w_{a,1}$, lb/sec	Corrected engine-inlet air flow, $w_{a,1}\sqrt{\theta_1}/\delta_2$, lb/sec	Tailpipe air flow, $w_{a,5}$, lb/sec	Scale jet thrust, $F_{j,s}$, lb	Corrected scale jet thrust, $F_{j,s}/\delta_2$, lb	Run
1243	1.618	1.188	2.491	113.8	165.5	112.2	5394	8,054	1
1310	1.806	1.576	2.617	113.4	166.2	111.8	6496	9,755	2
1412	2.001	1.832	2.813	112.5	166.7	110.8	7088	10,775	3
1526	2.195	2.049	3.073	113.7	166.1	112.0	7864	11,785	4
1681	2.484	2.341	3.357	113.2	166.4	111.4	8632	13,027	5
1200	1.565	1.151	2.398	111.9	162.7	110.2	5064	7,540	6
1265	1.732	1.500	2.528	112.0	162.9	110.3	6184	9,215	7
1384	1.967	1.812	2.763	112.4	163.7	110.7	7103	10,600	8
1631	2.397	2.259	3.249	112.2	162.7	110.3	8289	12,326	9
1143	1.474	1.082	2.287	107.6	156.6	105.8	4588	6,836	10
1160	1.524	1.259	2.323	108.2	155.9	106.4	5231	7,719	11
1239	1.688	1.503	2.470	108.1	156.1	106.2	5962	8,810	12
1384	1.946	1.812	2.780	108.0	156.3	106.1	6745	9,994	13
1573	2.235	2.112	3.129	107.4	156.3	105.5	7529	11,227	14
855	1.004	.806	1.719	82.1	120.3	81.1	2176	3,265	15
899	1.107	.953	1.808	82.1	120.9	80.9	2751	4,149	16
965	1.199	1.091	1.931	81.9	120.2	80.7	3221	4,841	17
1043	1.318	1.224	2.101	81.2	119.6	79.9	3693	5,566	18
1046	1.312	1.221	2.118	81.6	118.8	80.3	3636	5,433	19
1158	1.491	1.403	2.325	80.9	118.3	79.5	4158	5,346	20
1286	1.845	1.347	3.026	56.6	169.0	55.7	2944	9,748	21
1354	2.018	1.748	3.202	56.7	168.9	55.8	3489	11,553	22
1504	2.118	2.149	3.540	56.9	168.5	56.0	3976	13,083	23
1617	2.336	2.363	3.816	57.1	169.0	56.1	4185	13,794	24
1655	2.474	2.488	3.940	56.5	169.0	55.6	4310	14,362	25
1301	1.763	1.279	2.843	60.4	167.2	59.5	3097	9,190	26
1414	2.049	1.837	3.082	60.4	167.8	59.4	3898	11,595	27
1481	2.171	1.998	3.245	60.5	168.2	59.5	4098	12,247	28
1506	2.229	2.069	3.293	60.2	168.1	59.2	4185	12,526	29
1602	2.400	2.251	3.540	60.9	168.7	59.9	4445	13,249	30
1680	2.566	2.421	3.685	61.1	168.6	60.0	4604	13,682	31
1158	1.731	1.257	2.743	56.5	166.6	55.7	2718	8,903	32
1216	1.885	1.622	2.883	56.6	167.1	55.8	3210	10,531	33
1287	2.076	1.891	3.071	56.4	166.7	55.5	3463	11,380	34
1469	2.425	2.279	3.512	56.7	166.9	55.8	3980	13,058	35
1574	2.457	2.460	3.712	56.5	167.3	55.5	4132	13,597	36
1110	1.580	1.151	2.440	58.4	161.0	57.4	2598	7,700	37
1118	1.605	1.267	2.462	58.4	161.6	57.5	2720	8,083	38
1161	1.711	1.462	2.544	58.2	161.5	57.3	3032	9,010	39
1234	1.872	1.695	2.704	57.7	160.4	56.8	3350	9,970	40
1361	2.125	1.986	3.027	58.0	161.0	56.9	3770	11,237	41
1528	2.424	2.294	3.347	57.8	160.5	56.7	4177	12,413	42
998	1.385	1.008	2.179	53.2	147.3	52.2	1976	5,864	43
1003	1.399	1.098	2.196	53.2	148.6	52.3	2128	6,369	44
1042	1.499	1.276	2.288	53.5	147.4	52.6	2497	7,370	45
1115	1.661	1.505	2.470	53.8	148.9	52.8	2763	8,223	46
1158	1.727	1.590	2.526	52.8	147.0	51.9	2928	8,688	47
1202	1.834	1.706	2.663	53.3	148.1	52.4	3108	9,264	48
1370	2.114	2.001	3.031	53.1	147.6	52.1	3458	10,307	49
865	1.141	.876	1.913	47.6	130.2	46.9	1414	4,161	50
874	1.169	.940	1.925	47.3	130.6	46.5	1532	4,541	51
909	1.244	1.063	2.004	47.0	129.9	46.3	1745	5,172	52
978	1.340	1.214	2.136	46.4	128.8	45.7	1980	5,860	53
975	1.388	1.212	2.132	46.5	128.2	45.7	1963	5,785	54
1019	1.410	1.302	2.214	45.5	127.2	44.7	2093	6,211	55
1058	1.520	1.413	2.356	47.0	129.6	46.2	2295	6,802	56
1118	1.599	1.496	2.467	46.1	127.8	45.2	2404	7,134	57
757	.915	.760	1.646	38.9	107.8	38.3	823	2,432	58
792	.982	.856	1.722	38.9	107.8	38.3	1047	3,090	59
845	1.070	.973	1.828	39.0	108.5	38.4	1293	3,832	60
897	1.138	1.053	1.941	38.9	108.0	38.2	1427	4,223	61
980	1.257	1.179	2.127	38.6	106.9	37.9	1601	4,731	62
1358	1.883	1.354	3.188	27.7	167.0	27.2	1481	9,920	63
1432	2.206	1.913	3.387	27.5	168.5	27.1	1719	11,694	64
1526	2.254	2.032	3.576	27.6	166.9	27.1	1882	12,639	65
1601	2.391	2.205	3.747	27.5	167.3	27.0	1961	13,304	66
1682	2.561	2.381	3.993	27.5	168.1	27.0	2077	14,091	67

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TABLE I. - Concluded. INLET GUIDE VANES OPEN, COMPRESSOR

(a) Concluded. Variable

Run	Reynolds number index, $\delta_2/\varphi_1\sqrt{\theta_1}$	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Cold actual exhaust-nozzle area, A_{10}, sq ft	Ambient static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Turbine-outlet total pressure, P_5, lb/sq ft abs	Exhaust-nozzle-inlet total pressure, P_9, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Exhaust-nozzle-inlet total temperature, T_9, °R
68	0.203	6173	6644	4.42	206	354	651	488	448	1351
69	.202	6173	6629	3.54	209	355	741	653	450	1466
70	.194	5934	6588	4.42	185	312	570	410	421	1244
71	.195	5929	6591	3.63	185	312	634	549	420	1331
72	.194	5934	6581	3.36	186	312	674	607	422	1384
73	.194	5931	6585	3.16	186	312	---	658	421	1459
74	.198	5790	6177	4.42	209	353	591	431	456	1234
75	.198	5791	6192	3.70	206	352	667	579	454	1322
76	.199	5787	6187	3.48	209	354	731	665	454	1410
77	.199	5793	6194	3.13	208	354	771	711	454	1467
78	.198	5792	6173	2.99	207	354	826	770	457	1566
79	.199	5790	6191	2.85	209	353	877	824	454	1650
80	.192	5397	5978	4.42	187	311	505	362	423	1078
81	.194	5399	5988	3.30	187	312	601	541	422	1209
82	.194	5396	5998	3.01	180	310	667	618	420	1312
83	.196	5406	6024	2.79	185	312	737	690	418	1423
84	.198	5252	5603	4.42	205	354	488	359	456	1055
85	.197	5248	5587	3.70	206	354	542	465	458	1120
86	.199	5255	5607	3.33	207	355	593	534	456	1199
87	.199	5248	5599	3.10	206	355	642	592	456	1271
88	.199	5247	5598	2.85	209	356	702	656	456	1392
89	.198	4885	5206	4.42	206	355	403	308	457	924
90	.199	4872	5192	3.95	205	356	428	356	457	948
91	.198	4880	5201	3.45	205	355	468	416	457	1021
92	.200	4888	5209	3.13	205	359	509	465	457	1088
93	.199	4879	5200	2.82	205	356	573	535	457	1210

(b) Fixed exhaust-nozzle

Run	Reynolds number index, $\delta_2/\varphi_1\sqrt{\theta_1}$	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Cold actual exhaust-nozzle area, A_{10}, sq ft	Ambient static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Turbine-outlet total pressure, P_5, lb/sq ft abs	Exhaust-nozzle-inlet total pressure, P_9, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Exhaust-nozzle-inlet total temperature, T_9, °R
1	0.702	6174	6354	3.01	812	1378	3306	3111	490	1646
2	.697	6001	6182	3.01	814	1365	3099	2910	489	1542
3	.694	5802	5965	3.01	807	1367	2915	2735	491	1457
4	.693	5200	5336	3.01	817	1372	2167	2015	493	1176
5	.697	4852	4978	3.01	821	1379	1781	1657	493	1022
6	.402	6116	6751	3.01	397	657	1700	1599	426	1630
7	.392	5835	6411	3.01	385	648	1573	1474	430	1461
8	.400	5613	6167	3.01	395	660	1468	1370	430	1378
9	.399	5460	6005	3.01	397	658	1409	1315	429	1302
10	.388	5075	5518	3.01	391	659	1157	1073	439	1140
11	.400	4720	5198	3.01	395	657	975	903	428	974
12	.404	4386	4841	3.01	394	660	797	740	426	849
13	.294	6097	6652	3.01	295	494	1267	1189	436	1645
14	.297	5992	6567	3.01	298	494	1235	1159	432	1587
15	.299	5820	6386	3.01	297	496	1184	1107	431	1498
16	.297	5623	6170	3.01	294	493	1127	1052	431	1411
17	.300	5357	5886	3.01	297	495	1024	952	430	1310
18	.298	5135	5628	3.01	294	496	937	871	432	1215
19	.299	4697	5148	3.01	300	498	722	668	432	1003
20	.194	5997	6543	3.01	195	326	829	774	438	1654
21	.199	5818	6405	3.01	187	327	798	744	428	1543
22	.197	5625	6130	3.01	191	326	755	702	430	1447
23	.200	5481	6036	3.01	193	328	724	672	428	1386
24	.197	5097	5561	3.01	194	331	603	556	436	1208
25	.196	4870	5307	3.01	208	331	528	487	437	1111
26	.197	4729	5183	3.01	180	327	494	455	432	1062
27	.150	5901	6446	3.01	169	252	637	592	435	1660
28	.151	5642	6156	3.01	173	254	593	549	436	1540
29	.151	5486	5979	3.01	173	255	560	518	437	1452
30	.149	5126	5580	3.01	173	252	468	431	438	1282
31	.149	4777	5170	3.01	167	256	385	354	443	1119
32	.100	5547	5997	3.01	152	173	480	377	444	1654
33	.100	5464	5963	3.01	150	169	381	352	439	1582
34	.101	5123	5539	3.01	149	175	330	304	444	1399

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ACCELERATION BLEEDS CLOSED (HIGH-SPEED CONFIGURATION)

exhaust-nozzle area.

Manufacturer's control-system thermocouple readings, °R	Engine total-pressure ratio, P_5/P_2	Engine and tailpipe total-pressure ratio, P_9/P_2	Engine total-temperature ratio, T_9/T_1	Engine-inlet air flow, $w_{a,1}$, lb/sec	Corrected engine-inlet air flow, $w_{a,1}\sqrt{\theta_1}/\delta_2$, lb/sec	Tailpipe air flow, $w_{a,5}$, lb/sec	Scale jet thrust, $F_{j,s}$, lb	Corrected scale jet thrust, $F_{j,s}/\delta_2$, lb	Run
1369	1.839	1.322	3.016	30.2	167.8	29.7	1625	9,713	68
1486	2.087	1.839	3.258	30.0	166.5	29.5	1964	11,704	69
1256	1.827	1.314	2.955	27.3	166.6	26.9	1352	9,172	70
1340	2.032	1.760	3.169	27.3	166.7	26.8	1652	11,208	71
1416	2.160	1.946	3.280	27.1	166.0	26.7	1753	11,893	72
1472	-----	2.109	3.466	27.1	165.8	26.7	1840	12,483	73
1247	1.674	1.221	2.706	28.9	162.2	28.3	1392	8,345	74
1333	1.895	1.645	2.912	28.9	162.4	28.3	1706	10,264	75
1424	2.065	1.879	3.106	29.0	162.4	28.5	1862	11,130	76
1488	2.178	2.008	3.231	29.0	162.0	28.4	1967	11,757	77
1576	2.333	2.175	3.427	28.8	161.8	28.3	2069	12,367	78
1663	2.484	2.334	3.634	28.9	162.1	28.3	2154	12,914	79
1086	1.624	1.164	2.548	25.7	158.0	25.4	1094	7,442	80
1211	1.926	1.734	2.865	25.8	158.1	25.5	1472	9,986	81
1310	2.152	1.994	3.124	25.9	159.0	25.5	1633	11,147	82
1426	2.362	2.212	3.404	26.1	158.9	25.6	1765	11,974	83
1059	1.379	1.014	2.314	25.8	144.7	25.3	999	5,971	84
1128	1.531	1.314	2.445	25.5	143.2	25.0	1243	7,430	85
1208	1.670	1.504	2.629	25.5	142.3	25.0	1391	8,290	86
1280	1.808	1.668	2.787	25.4	142.0	24.9	1502	8,951	87
1392	1.972	1.843	3.053	25.4	141.4	24.8	1598	9,501	88
927	1.135	.868	2.022	22.5	125.8	22.1	688	4,100	89
954	1.202	1.000	2.074	22.3	124.2	21.9	812	4,826	90
1029	1.318	1.172	2.234	22.1	123.6	21.7	988	5,888	91
1093	1.418	1.295	2.381	22.2	122.6	21.7	1088	6,411	92
1217	1.610	1.503	2.648	21.4	119.3	20.9	1217	7,235	93

area (near rated).

Manufacturer's control-system thermocouple readings, °R	Engine total-pressure ratio, P_5/P_2	Engine and tailpipe total-pressure ratio, P_9/P_2	Engine total-temperature ratio, T_9/T_1	Engine-inlet air flow, $w_{a,1}$, lb/sec	Corrected engine-inlet air flow, $w_{a,1}\sqrt{\theta_1}/\delta_2$, lb/sec	Tailpipe air flow, $w_{a,5}$, lb/sec	Scale jet thrust, $F_{j,s}$, lb	Corrected scale jet thrust, $F_{j,s}/\delta_2$, lb	Run
1663	2.399	2.258	3.359	112.3	167.5	110.5	8335	12,780	1
1550	2.270	2.132	3.153	109.8	165.2	108.2	7765	12,037	2
1460	2.132	2.001	2.967	106.4	160.2	104.8	7150	11,068	3
1173	1.579	1.469	2.385	89.8	135.0	88.6	4706	7,258	4
1023	1.292	1.202	2.073	78.1	116.8	77.0	3356	5,150	5
1667	2.588	2.434	3.826	58.3	168.2	56.5	4335	13,961	6
1474	2.427	2.275	3.398	56.8	168.9	55.2	3946	12,887	7
1379	2.221	2.076	3.205	56.4	162.9	54.7	3668	11,760	8
1301	2.141	1.998	3.035	55.6	160.7	54.0	3429	11,026	9
1141	1.756	1.628	2.597	49.0	143.0	47.6	2629	8,443	10
980	1.484	1.374	2.276	44.6	128.8	43.4	2009	6,470	11
854	1.208	1.121	1.993	39.0	111.9	37.9	1468	4,707	12
1663	2.565	2.407	3.773	42.8	167.9	42.0	3244	13,893	13
1599	2.500	2.346	3.674	42.8	167.1	42.0	3133	13,418	14
1499	2.387	2.252	3.476	42.7	165.9	41.9	2987	12,743	15
1406	2.286	2.134	3.274	41.7	163.0	40.9	2787	11,961	16
1307	2.069	1.923	3.047	40.1	155.9	39.2	2478	10,594	17
1219	1.889	1.756	2.813	37.6	146.2	36.7	2170	9,258	18
1010	1.450	1.341	2.322	31.9	123.7	31.3	1432	6,086	19
1669	2.543	2.374	3.794	27.9	165.8	27.3	2096	13,602	20
1551	2.440	2.275	3.605	28.1	165.3	27.6	2030	13,139	21
1446	2.316	2.153	3.365	27.3	161.2	26.8	1867	12,116	22
1385	2.207	2.049	3.238	27.1	158.7	26.6	1776	11,458	23
1210	1.822	1.680	2.771	24.2	141.5	23.8	1389	8,881	24
1113	1.595	1.471	2.542	21.9	128.3	21.5	1082	6,918	25
1070	1.511	1.391	2.458	20.8	122.8	20.3	1082	7,003	26
1692	2.528	2.349	3.816	21.3	163.7	20.8	1554	13,048	27
1561	2.335	2.161	3.532	20.9	159.7	20.5	1408	11,733	28
1462	2.196	2.031	3.323	20.2	153.4	19.8	1309	10,863	29
1287	1.857	1.710	2.927	18.2	140.2	17.9	998	8,380	30
1128	1.504	1.383	2.526	15.5	118.0	15.2	754	6,231	31
1694	2.358	2.179	3.725	12.7	151.1	12.4	836	10,220	32
1608	2.254	2.083	3.604	12.9	148.1	12.5	772	9,662	33
1421	1.886	1.737	3.151	11.8	131.9	11.5	608	7,352	34

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TABLE II. - INLET GUIDE VANES CLOSED, COMPRESSOR

(a) Open exhaust-

Run	Reynolds number index, $\delta_2/\varphi_1\sqrt{\theta_1}$	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Cold actual exhaust-nozzle area, A_{10}, sq ft	Ambient static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Turbine-outlet total pressure, P_5, lb/sq ft abs	Exhaust-nozzle-inlet total pressure, P_9, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Exhaust-nozzle-inlet total temperature, T_9, °R
1	0.404	6169	6817	4.42	394	658	897	673	425	1183
2	.402	5622	6205	4.42	392	656	804	616	426	977
3	.404	5433	5997	4.42	395	660	774	598	426	925
4	.403	5090	5625	4.42	393	656	712	562	425	830
5	.406	4727	5224	4.42	393	661	649	528	425	747
6	.401	4723	5201	4.42	393	658	639	520	428	757
7	.392	4548	4962	4.42	398	659	599	501	436	721
8	.401	4264	4718	4.42	394	659	553	478	428	666
9	.403	3907	4302	4.42	393	661	489	449	428	606
10	.398	3506	3843	4.42	393	662	455	429	432	584

(b) Fixed exhaust-nozzle

Run	Reynolds number index, $\delta_2/\varphi_1\sqrt{\theta_1}$	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$ rpm	Cold actual exhaust-nozzle area, A_{10}, sq ft	Ambient static pressure, p_0, lb/sq ft abs	Compressor-inlet total pressure, P_2, lb/sq ft abs	Turbine-outlet total pressure, P_5, lb/sq ft abs	Exhaust-nozzle-inlet total pressure, P_9, lb/sq ft abs	Engine-inlet total temperature, T_1, °R	Exhaust-nozzle-inlet total temperature, T_9, °R
1	0.395	6174	6775	2.99	389	655	1273	1196	431	1507
2	.399	5617	6185	3.01	391	655	1089	1016	428	1208
3	.399	5456	6001	3.01	395	658	1048	977	429	1147
4	.397	5095	5598	3.07	395	656	939	872	430	1023
5	.404	4721	5217	3.07	391	657	836	778	425	909
6	.402	4471	4923	3.07	397	660	746	696	428	850
7	.399	4268	4689	3.07	390	660	680	634	430	790
8	.398	3922	4299	3.07	398	662	597	562	432	719
9	.397	3499	3835	3.07	398	660	519	495	432	664
10	.391	3479	3813	3.07	395	661	517	492	432	664

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ACCELERATION BLEEDS OPEN (LOW-SPEED CONFIGURATION)

nozzle area.

Manufacturer's control-system thermocouple readings, °R	Engine total-pressure ratio, P_5/P_2	Engine and tailpipe total-pressure ratio, P_9/P_2	Engine total-temperature ratio, T_9/T_1	Engine-inlet air flow, $w_{a,1}$, lb/sec	Corrected engine-inlet air flow, $w_{a,1}\sqrt{\theta_1}/\delta_2$, lb/sec	Tailpipe air flow, $w_{a,5}$, lb/sec	Scale jet thrust, $F_{j,s}$, lb	Corrected scale jet thrust, $F_{j,s}/\delta_2$, lb	Run
1203	1.464	1.023	2.784	48.0	137.9	45.0	1870	6013	1
987	1.226	.939	2.293	46.9	135.3	43.9	1521	4906	2
934	1.173	.906	2.171	47.0	134.6	43.9	1392	4463	3
834	1.085	.857	1.953	45.4	130.7	42.3	1214	3916	4
751	.982	.799	1.758	43.1	123.1	40.0	906	2900	5
757	.971	.790	1.769	41.5	121.1	38.9	857	2756	6
726	.909	.760	1.654	38.7	113.8	36.1	700	2248	7
668	.839	.725	1.556	36.2	105.5	33.6	592	1901	8
610	.740	.679	1.416	31.1	90.4	28.7	338	1082	9
590	.687	.648	1.306	25.5	74.2	23.3	174	556	10

area (near rated).

CZ-4

Manufacturer's control-system thermocouple readings, °R	Engine total-pressure ratio, P_5/P_2	Engine and tailpipe total-pressure ratio, P_9/P_2	Engine total-temperature ratio, T_9/T_1	Engine-inlet air flow, $w_{a,1}$, lb/sec	Corrected engine-inlet air flow, $w_{a,1}\sqrt{\theta_1}/\delta_2$, lb/sec	Tailpipe air flow, $w_{a,5}$, lb/sec	Scale jet thrust, $F_{j,s}$, lb	Corrected scale jet thrust, $F_{j,s}/\delta_2$, lb	Run
1553	1.944	1.826	3.497	47.4	138.0	44.3	3028	9784	1
1218	1.663	1.551	2.822	46.8	135.6	43.8	2446	7903	2
1154	1.593	1.485	2.674	46.7	134.7	43.5	2309	7424	3
1026	1.431	1.329	2.379	44.9	130.0	41.7	1952	6297	4
915	1.272	1.184	2.139	42.5	122.1	39.3	1601	5156	5
854	1.130	1.055	1.986	38.3	111.4	35.6	1241	3979	6
798	1.030	.961	1.837	35.6	103.8	33.0	1032	3309	7
727	.902	.849	1.664	30.7	89.6	28.3	702	2244	8
674	.786	.750	1.537	25.0	73.0	22.8	414	1327	9
674	.782	.744	1.537	25.0	73.0	22.8	398	1274	10

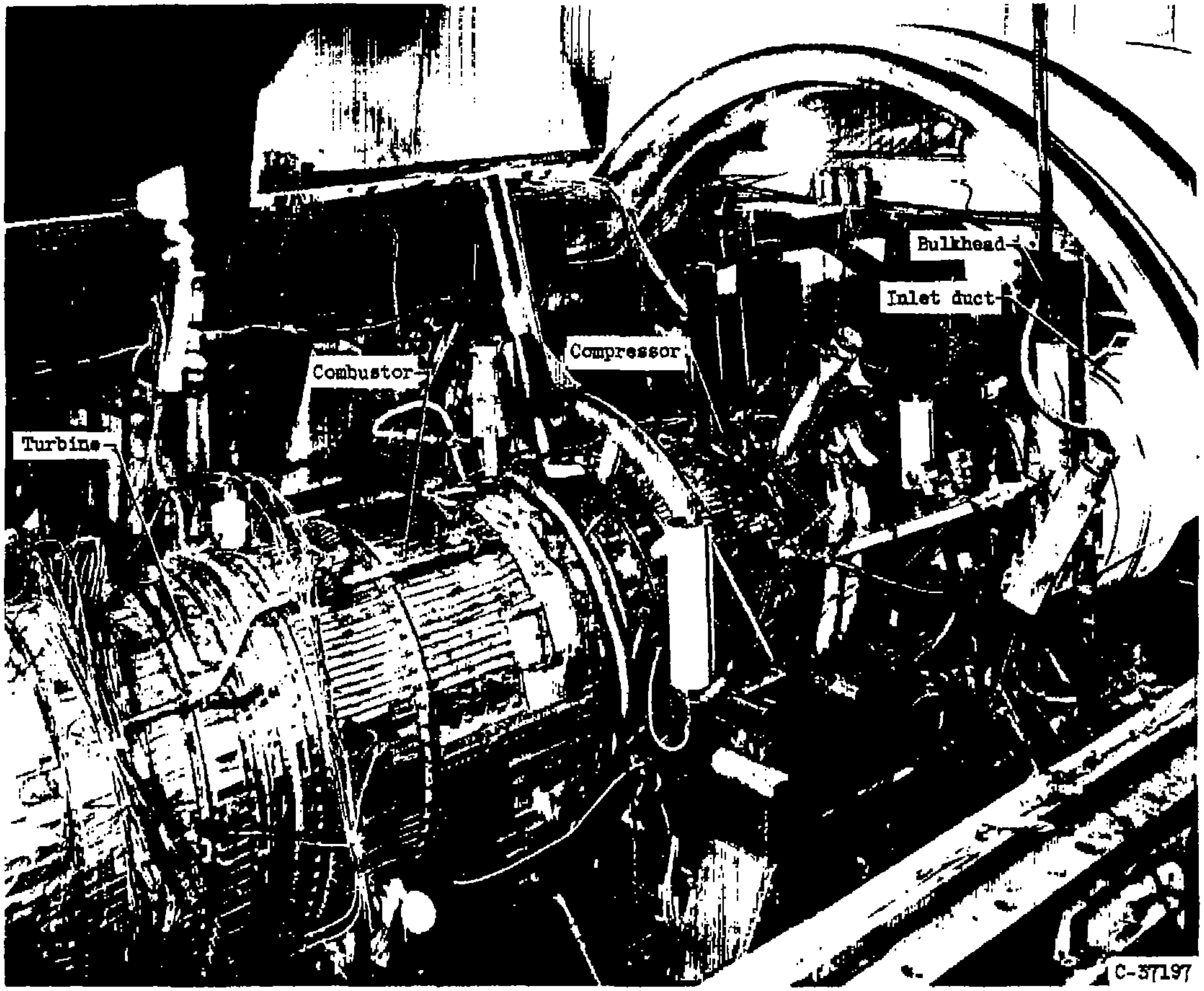

Figure 1. - Installation of J71-A-2 turbojet engine in altitude test chamber.

Station	Total pressures	Static pressures	Temperatures
1 (Venturi)	12	8	6
2	20	4	-
3	8	2	8
4	9	-	9
5	25	-	[a]37
9	14	-	14
10	-	4	-

[a]12 Allison and 25 NACA thermocouples.

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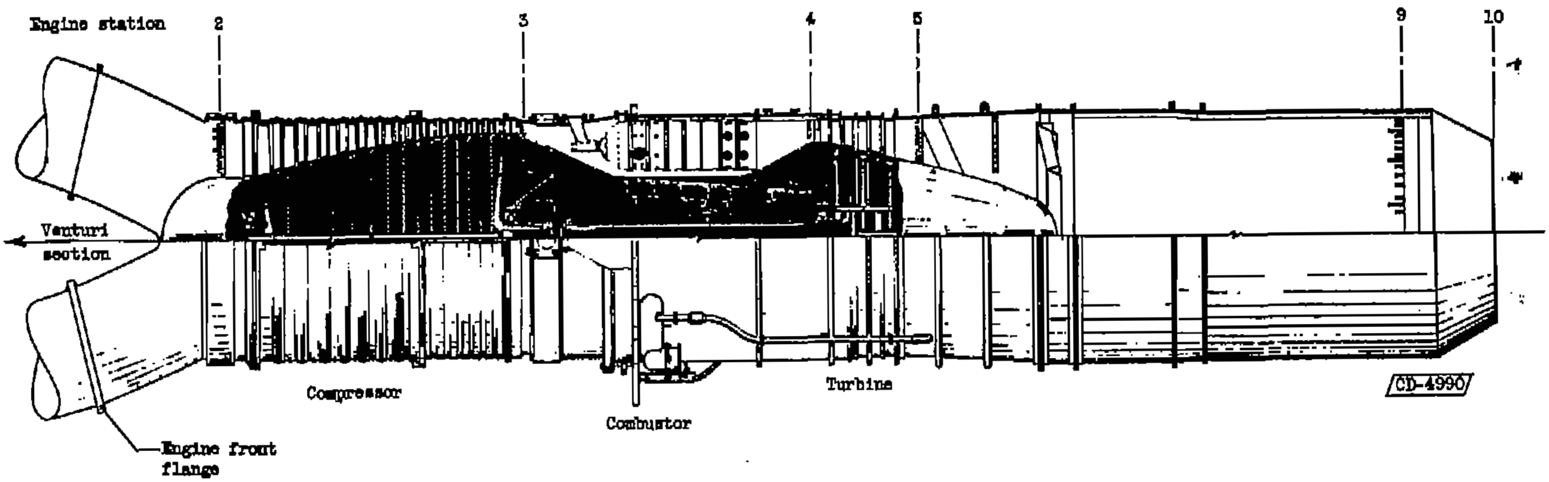

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Figure 2. - The J71-A-2 turbojet engine with instrumentation stations.

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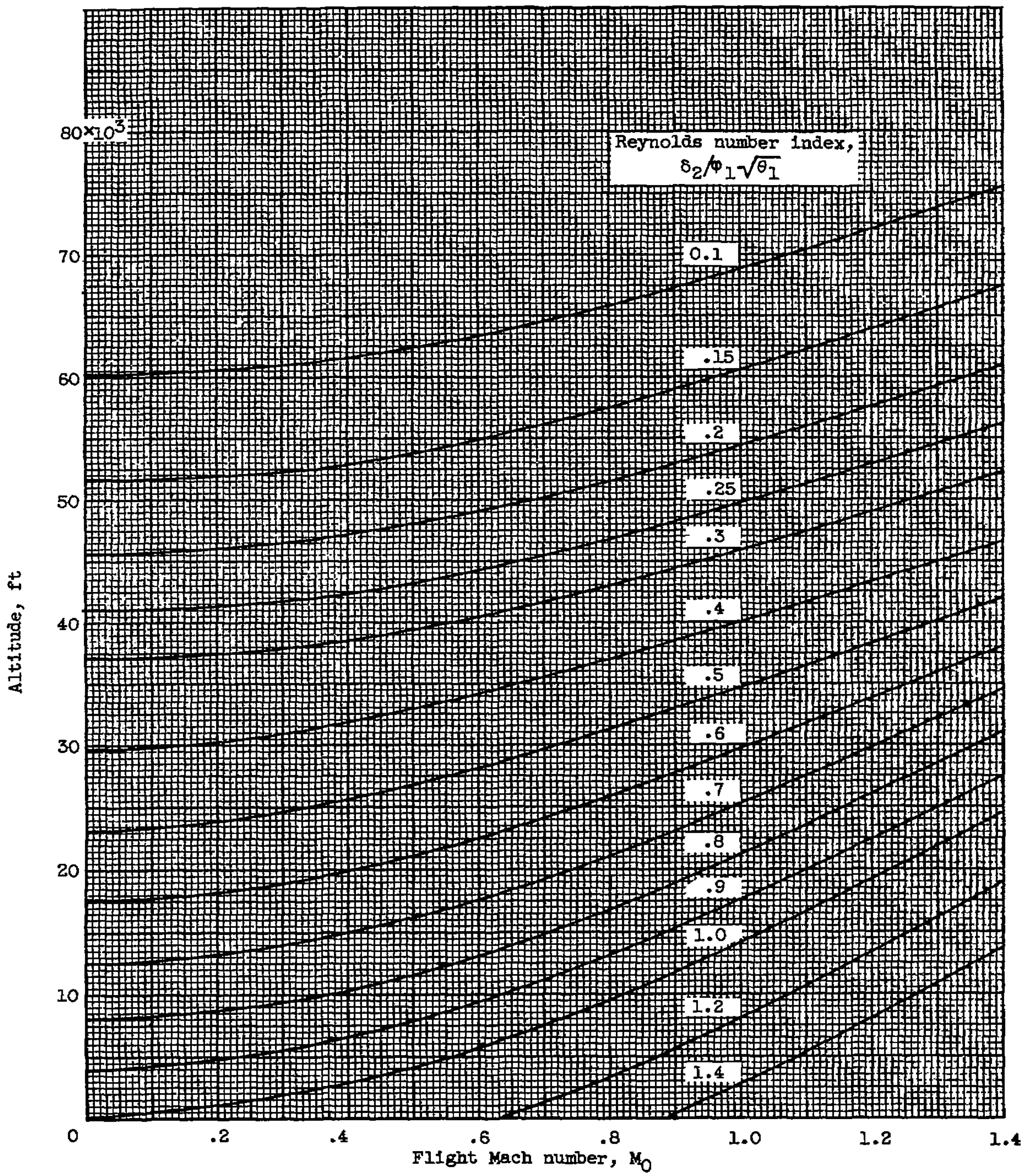

Figure 3. - Reynolds number index for a range of altitudes and flight Mach numbers. NACA standard atmosphere and 100-percent ram-pressure recovery.

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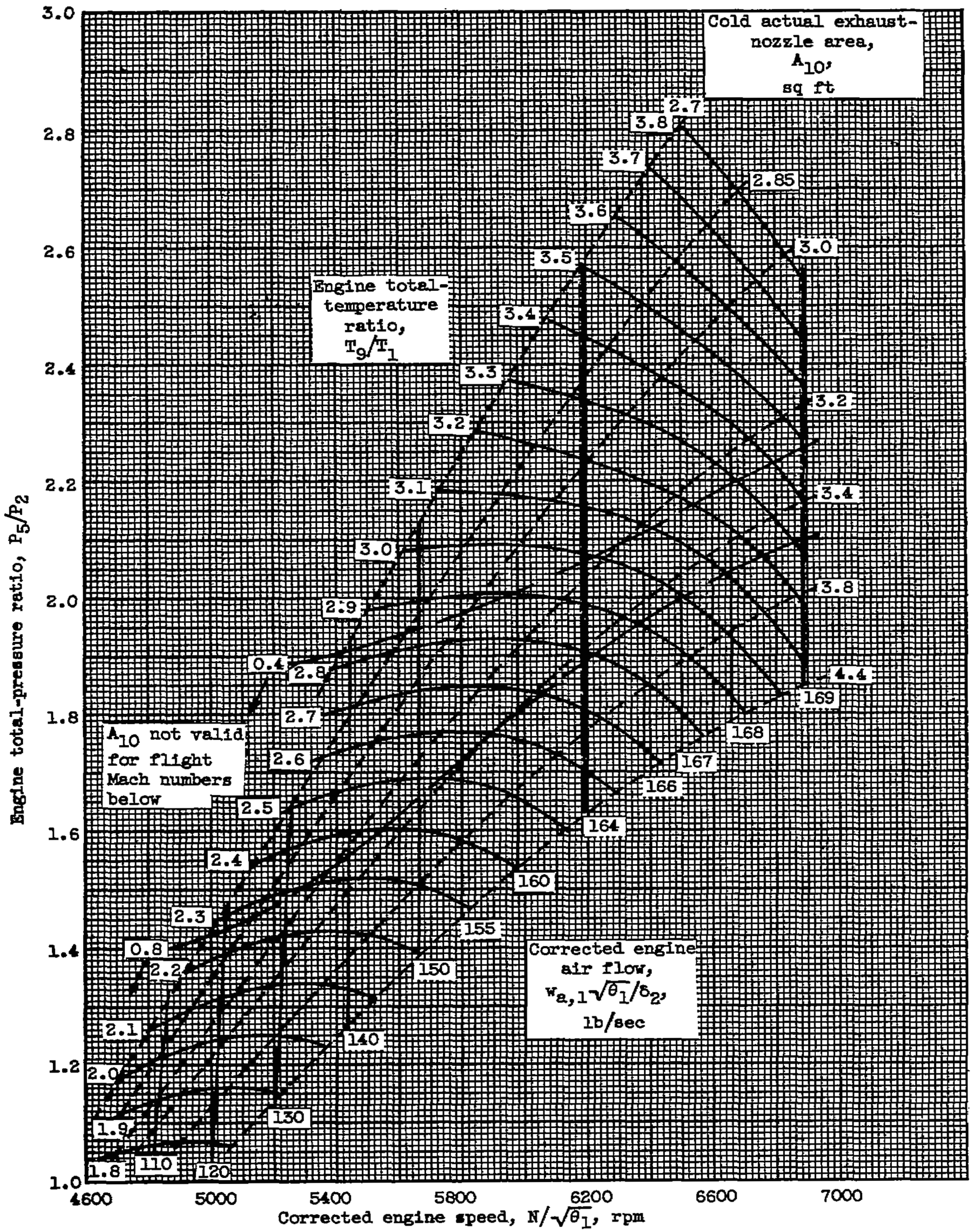

Figure 4. - Engine pumping characteristics. Reynolds number index, 0.4.

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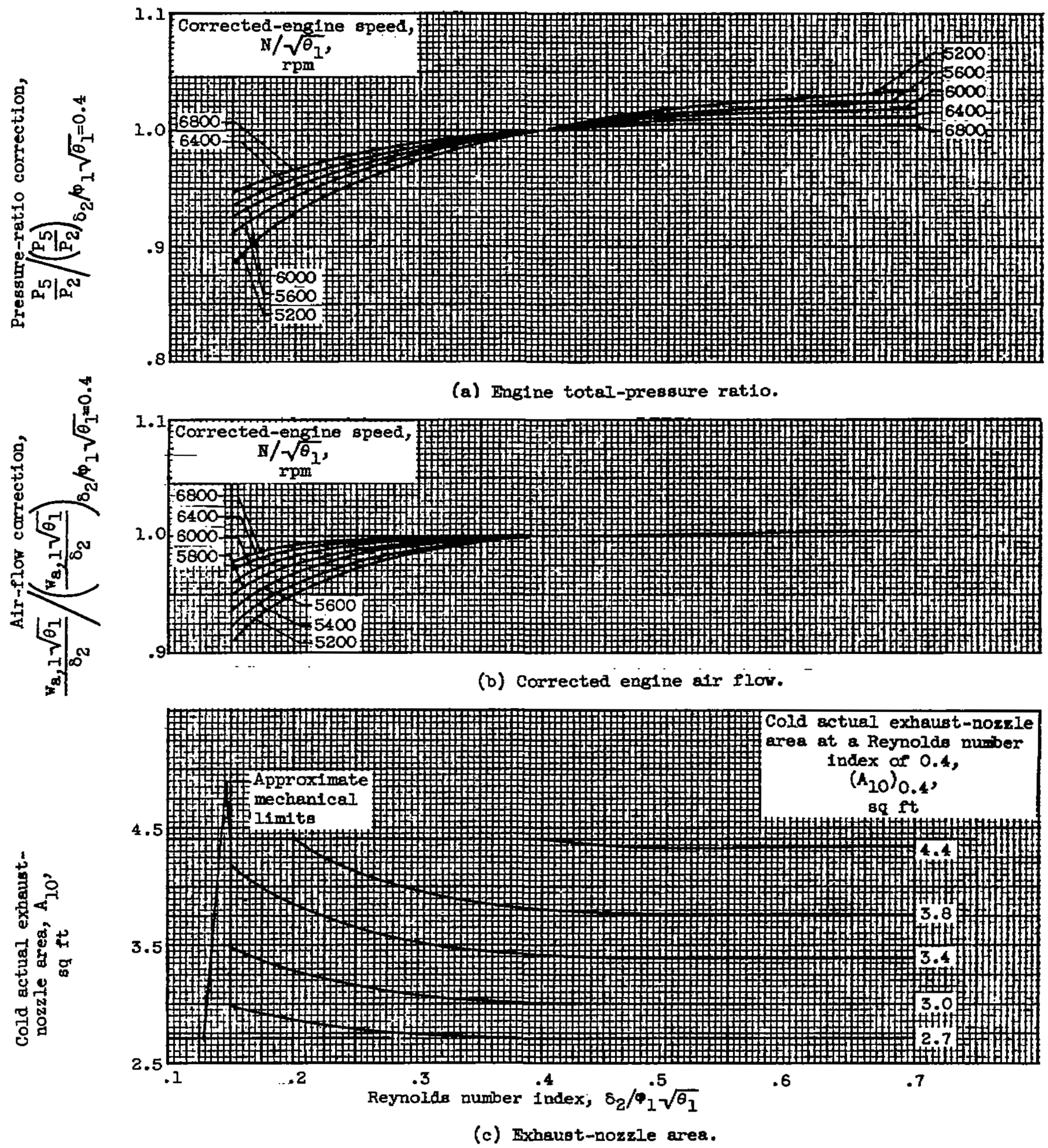

(a) Engine total-pressure ratio.

(b) Corrected engine air flow.

(c) Exhaust-nozzle area.

Figure 5. - Engine pressure ratio, air flow, and exhaust-nozzle-area corrections for a range of Reynolds number indices at a constant engine total-temperature ratio and corrected engine speed.

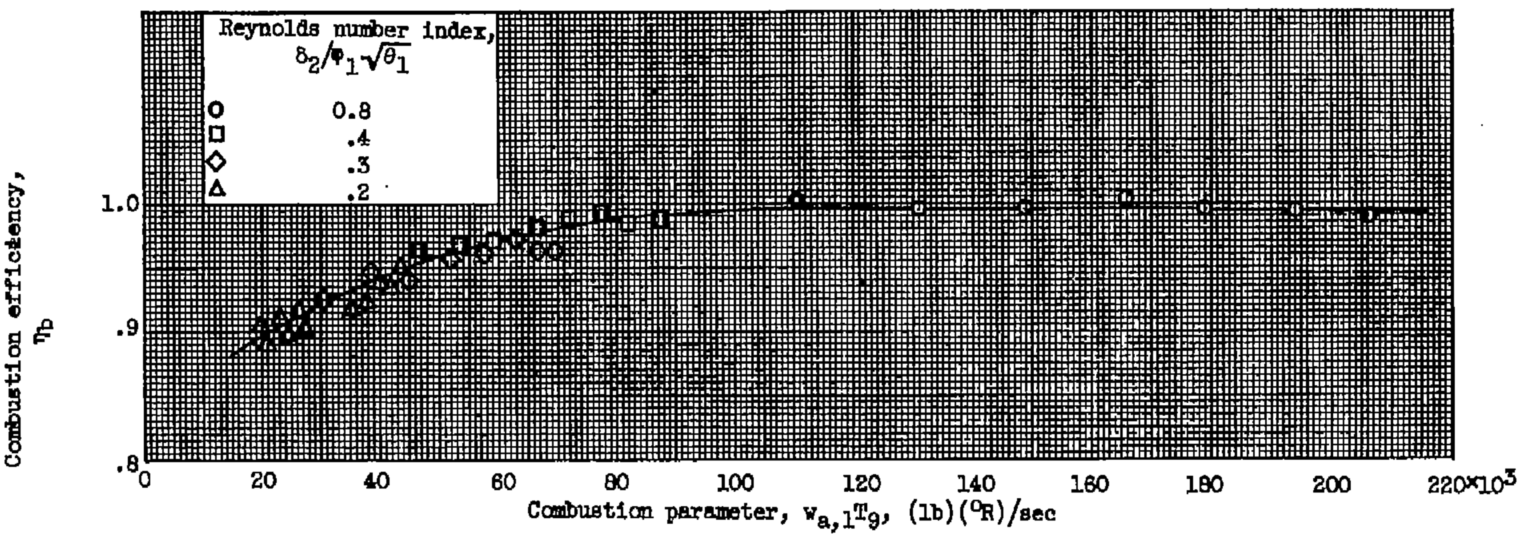

Figure 6. - Combustion efficiency.

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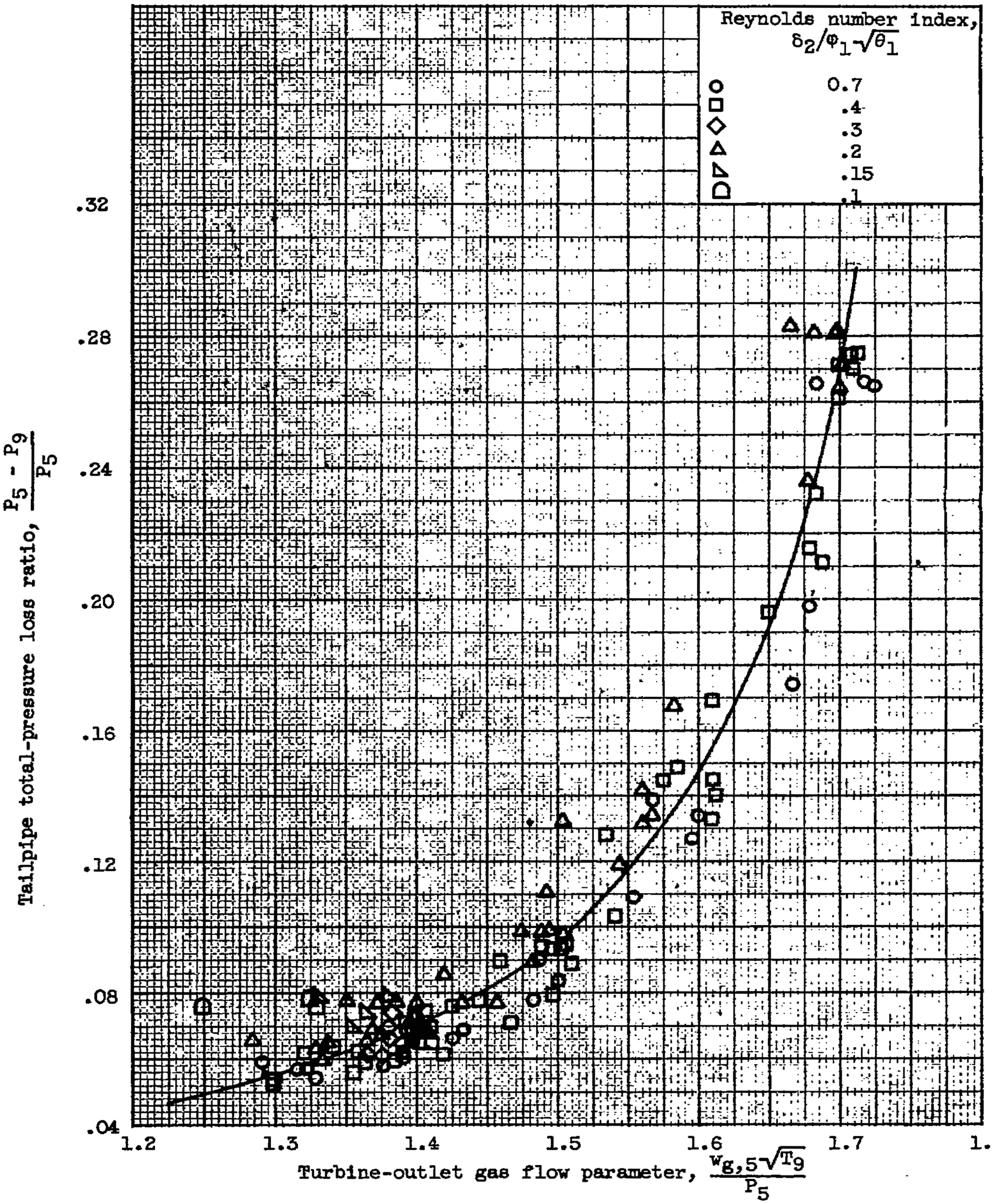

Figure 7. - Tailpipe pressure loss.

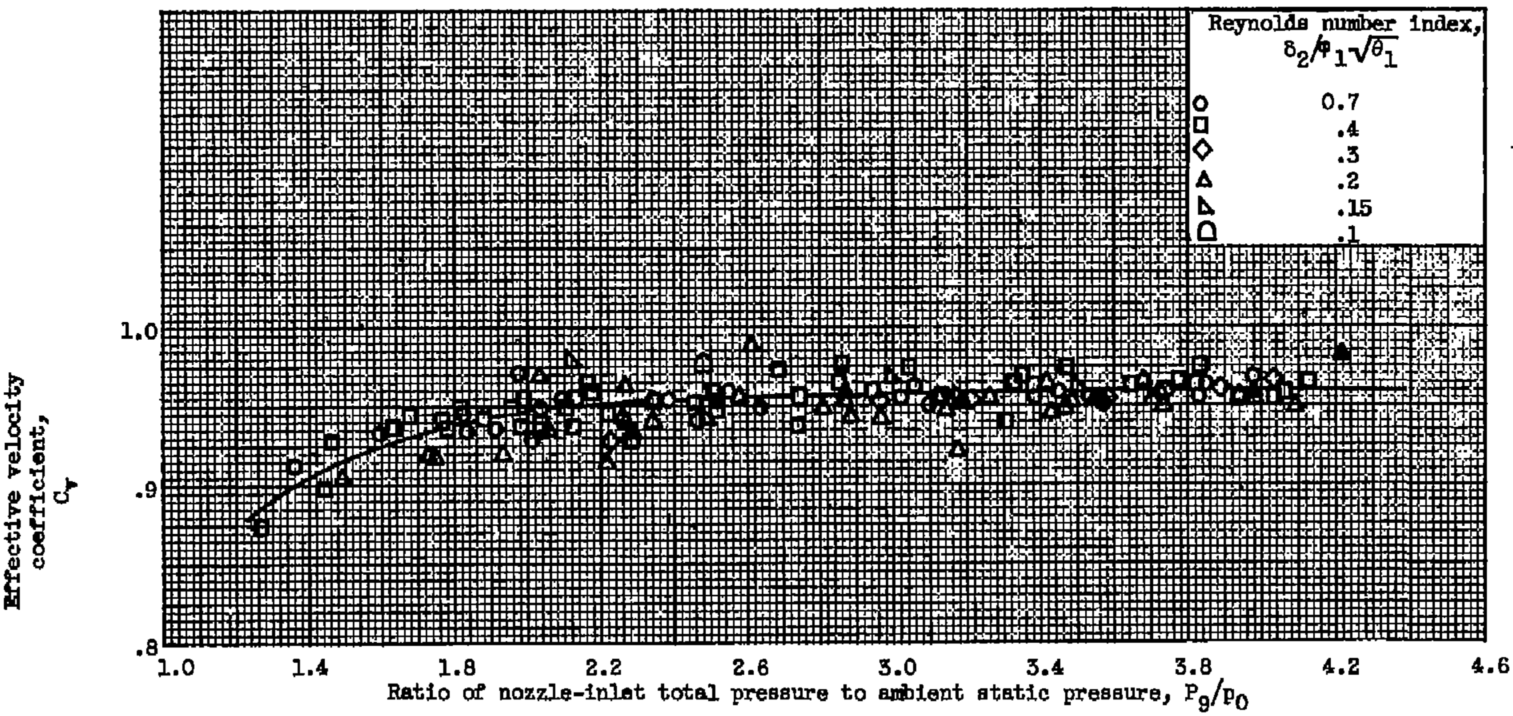

Figure 8. - Effective velocity coefficient of exhaust nozzle.

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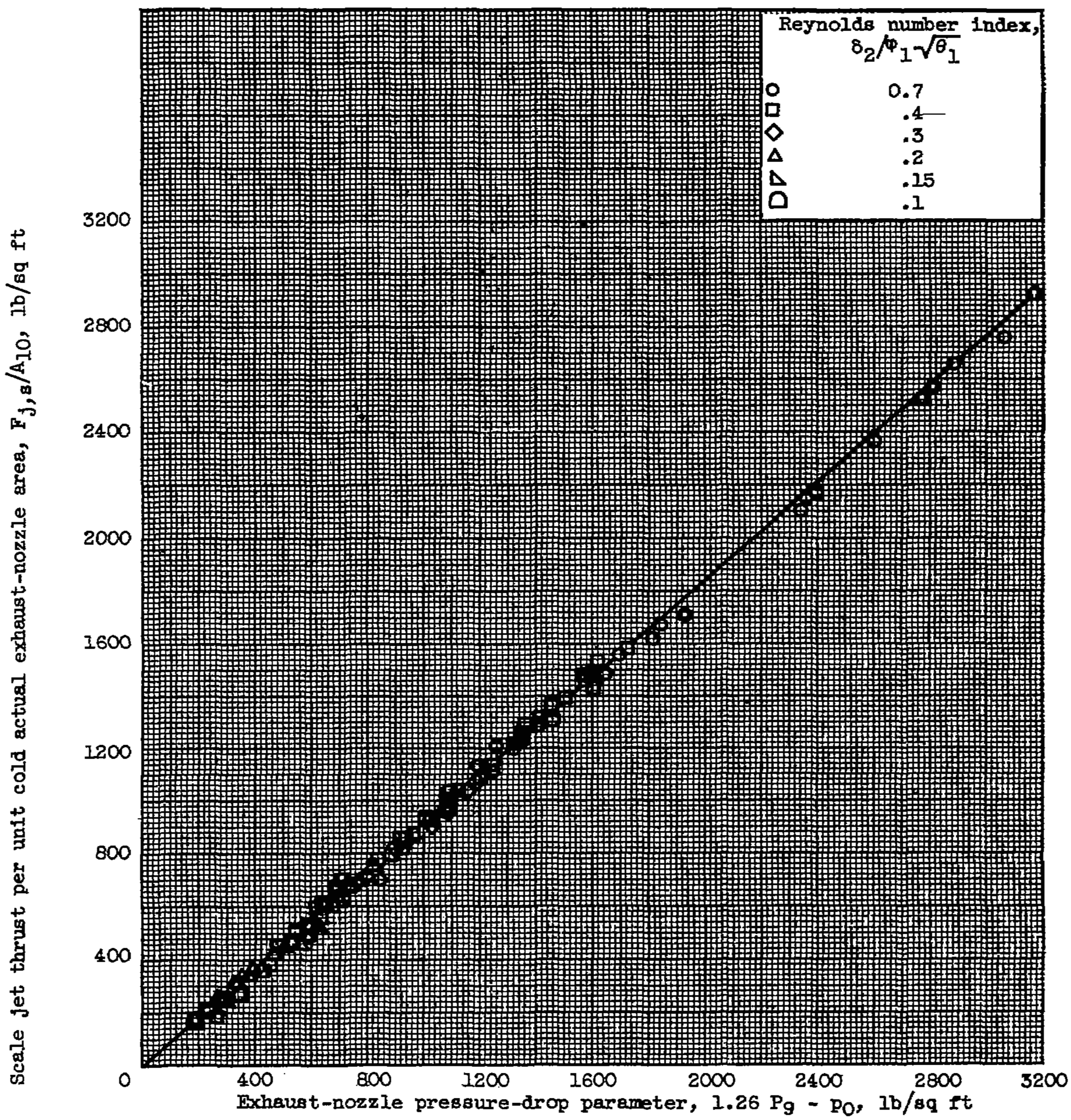

Figure 9. - Jet-thrust correlation.

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CZ-5 back

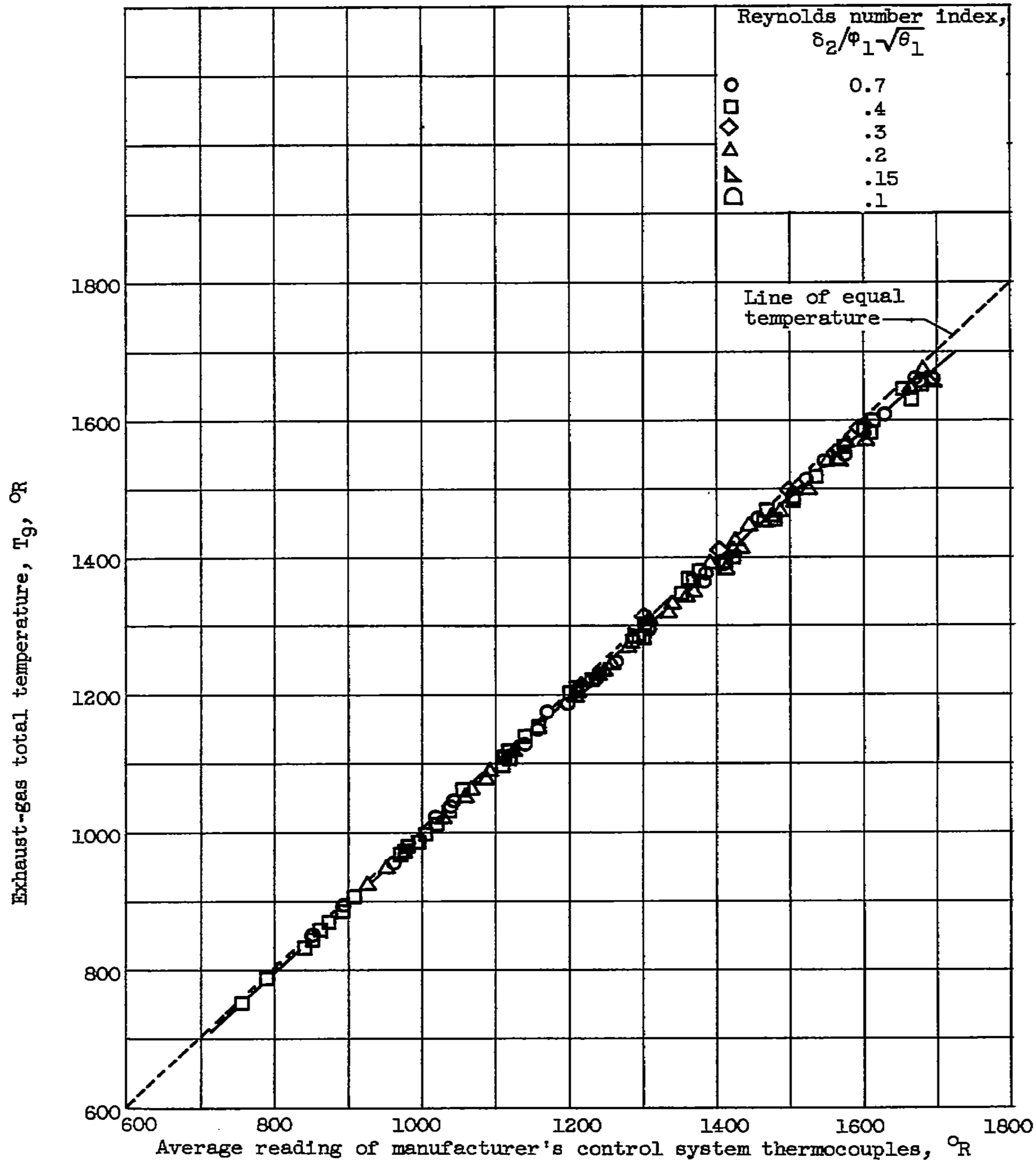

Figure 10. - Variation of manufacturer's control-system thermocouple readings with exhaust-gas total temperature.

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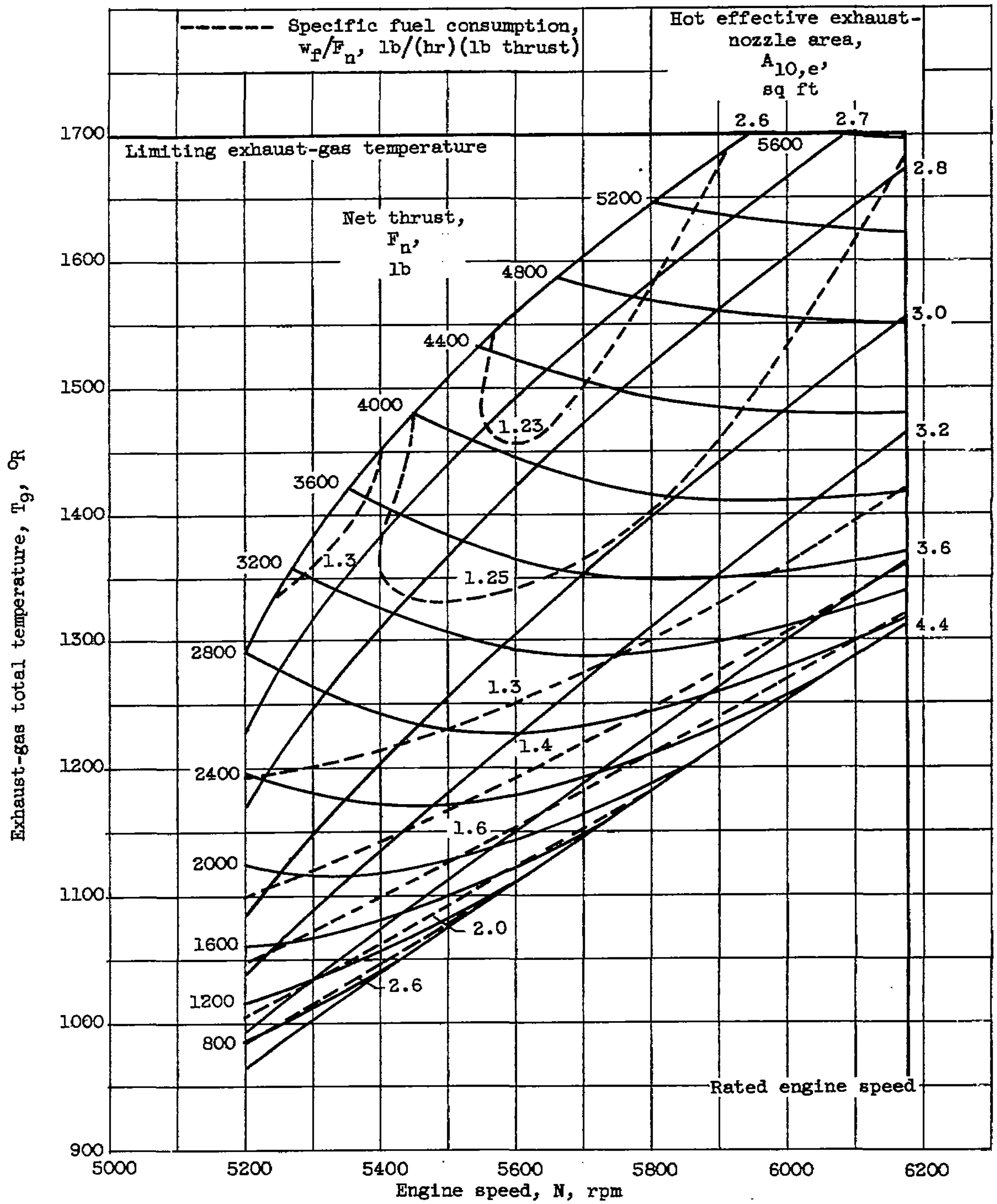

(a) Altitude, 20,000 feet; flight Mach number, 0.8.

Figure 11. - Engine performance maps.

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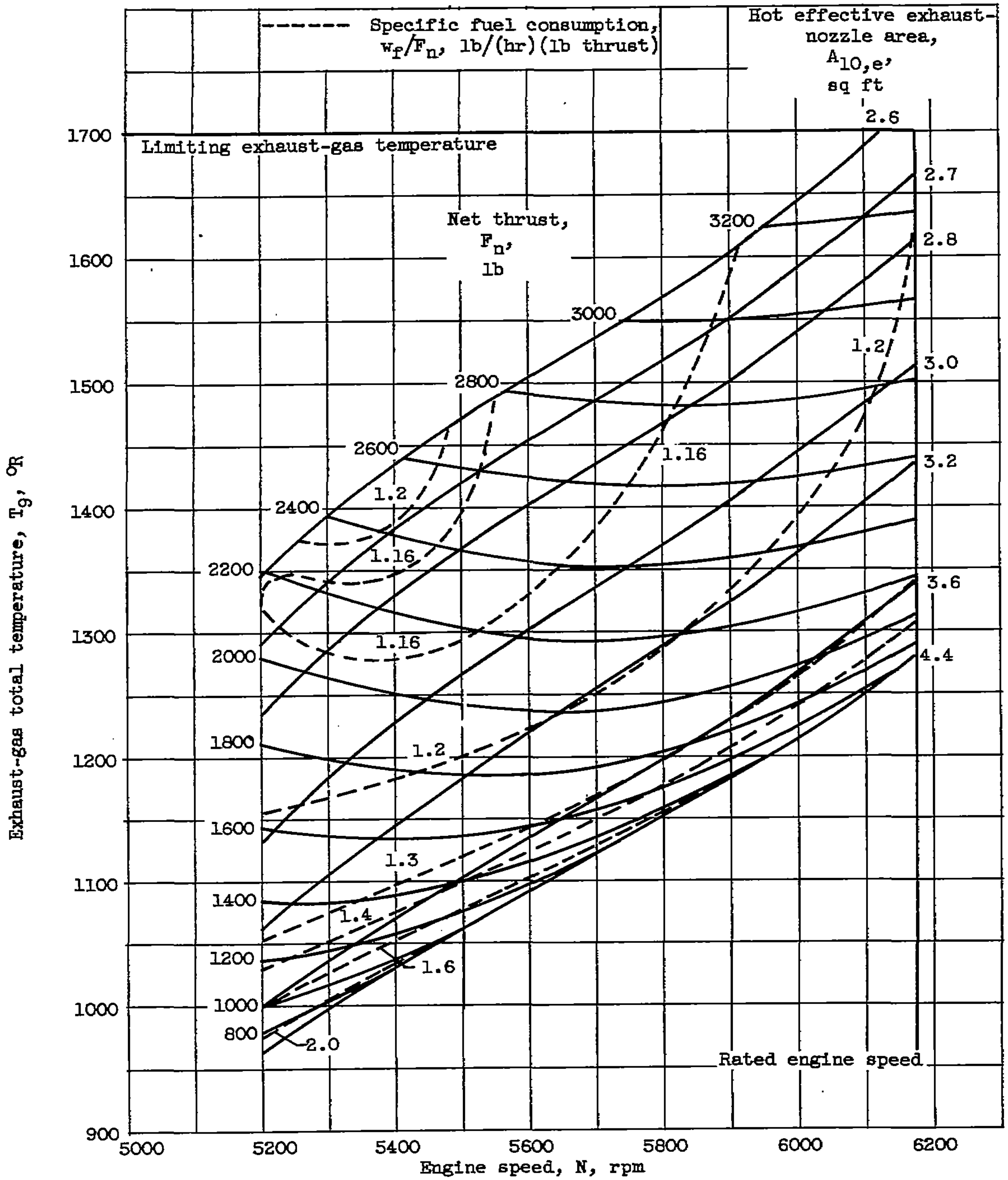

(b) Altitude, 35,000 feet; flight Mach number, 0.8.

Figure 11. - Continued. Engine performance maps.

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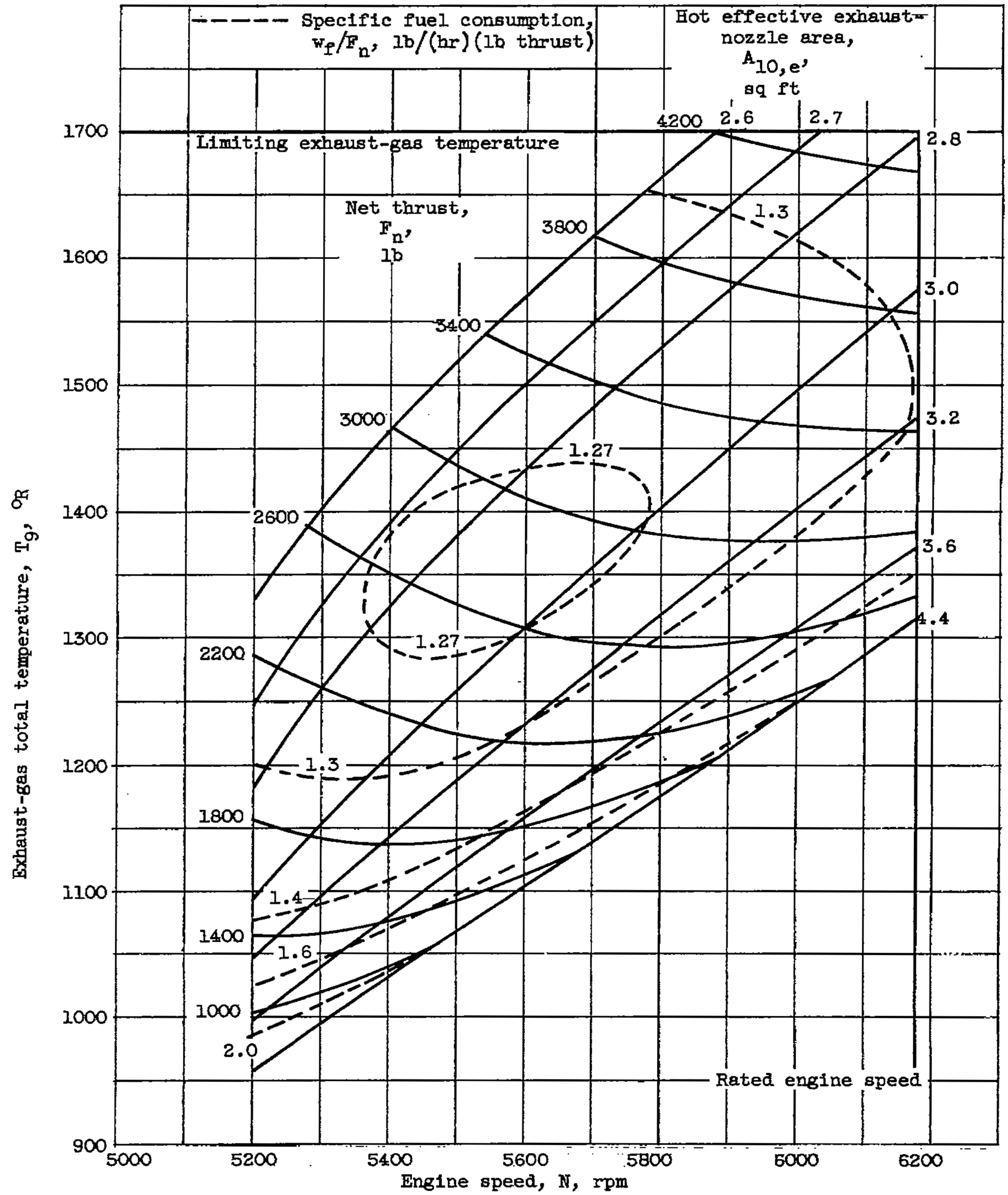

(c) Altitude, 35,000 feet; flight Mach number, 1.2.

Figure 11. - Continued. Engine performance maps.

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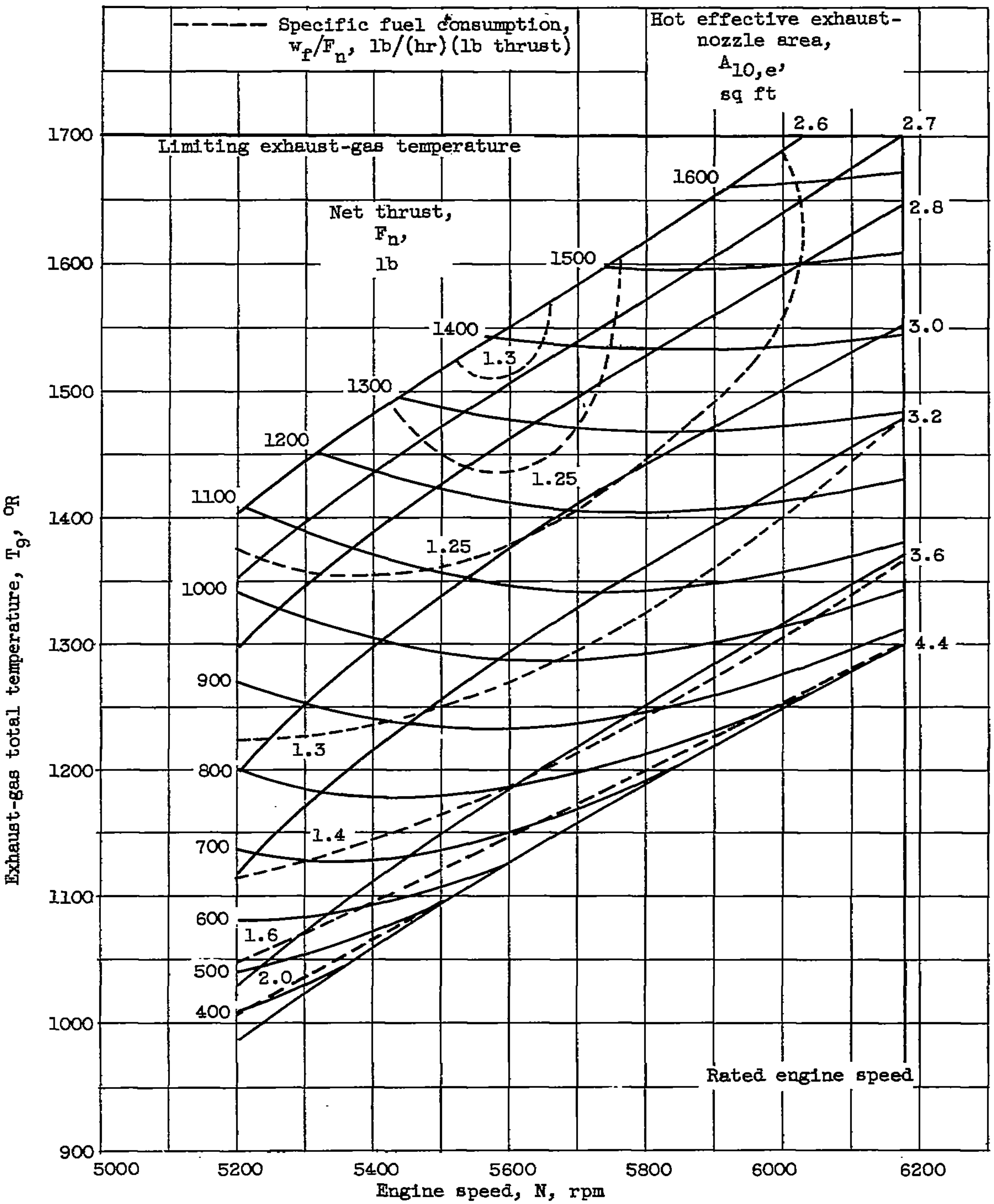
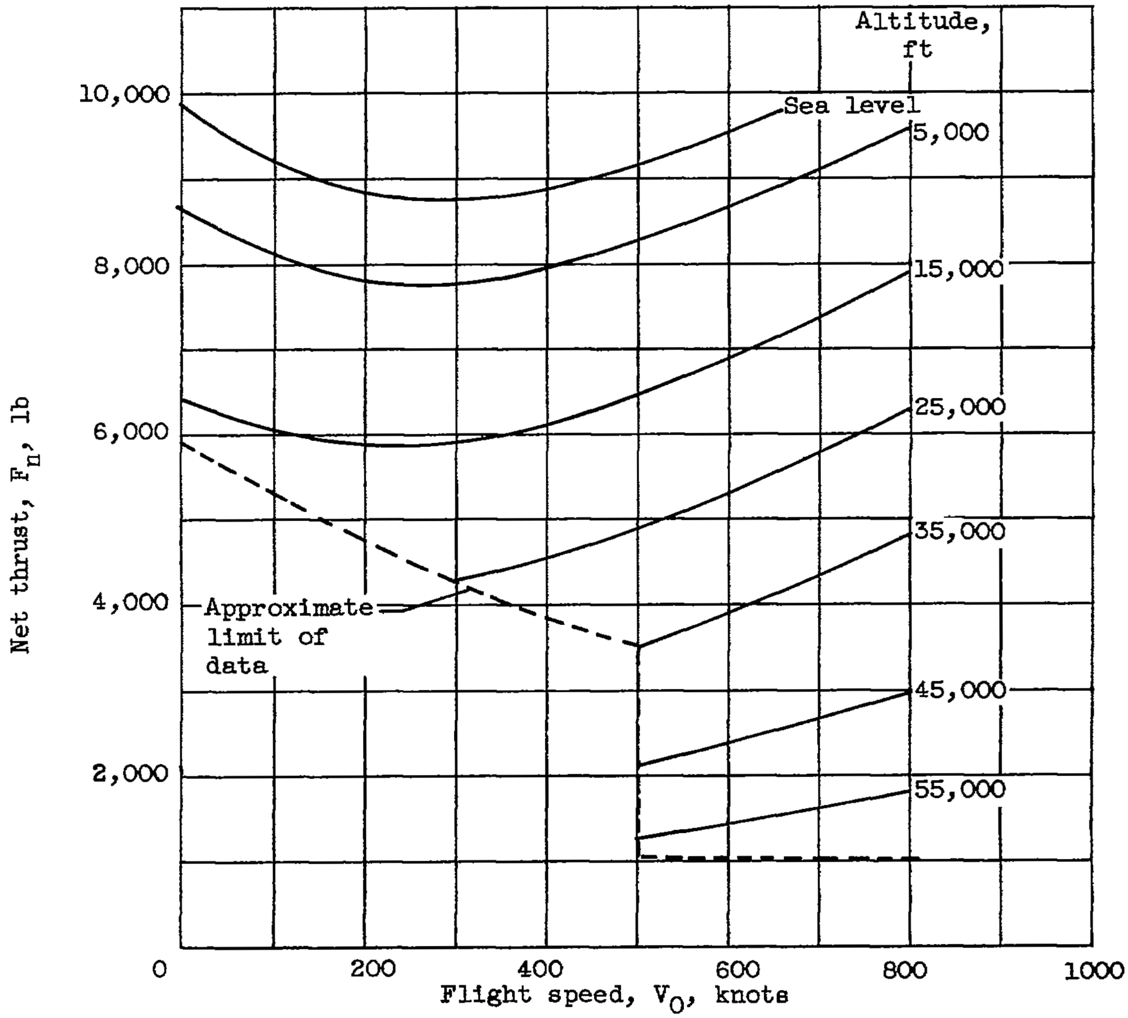


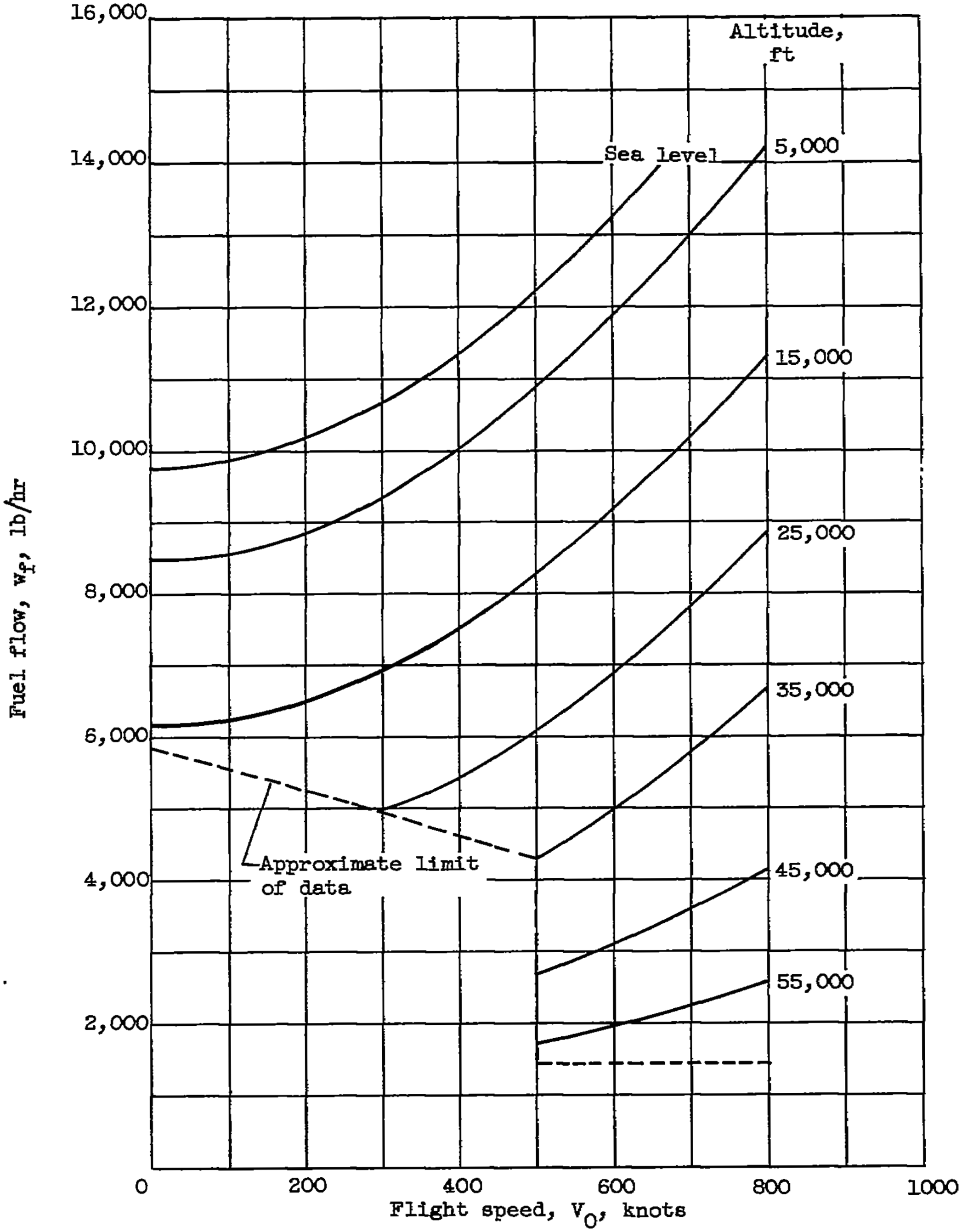
(d) Altitude, 50,000 feet; flight Mach number, 0.8.

Figure 11. - Concluded. Engine performance maps.



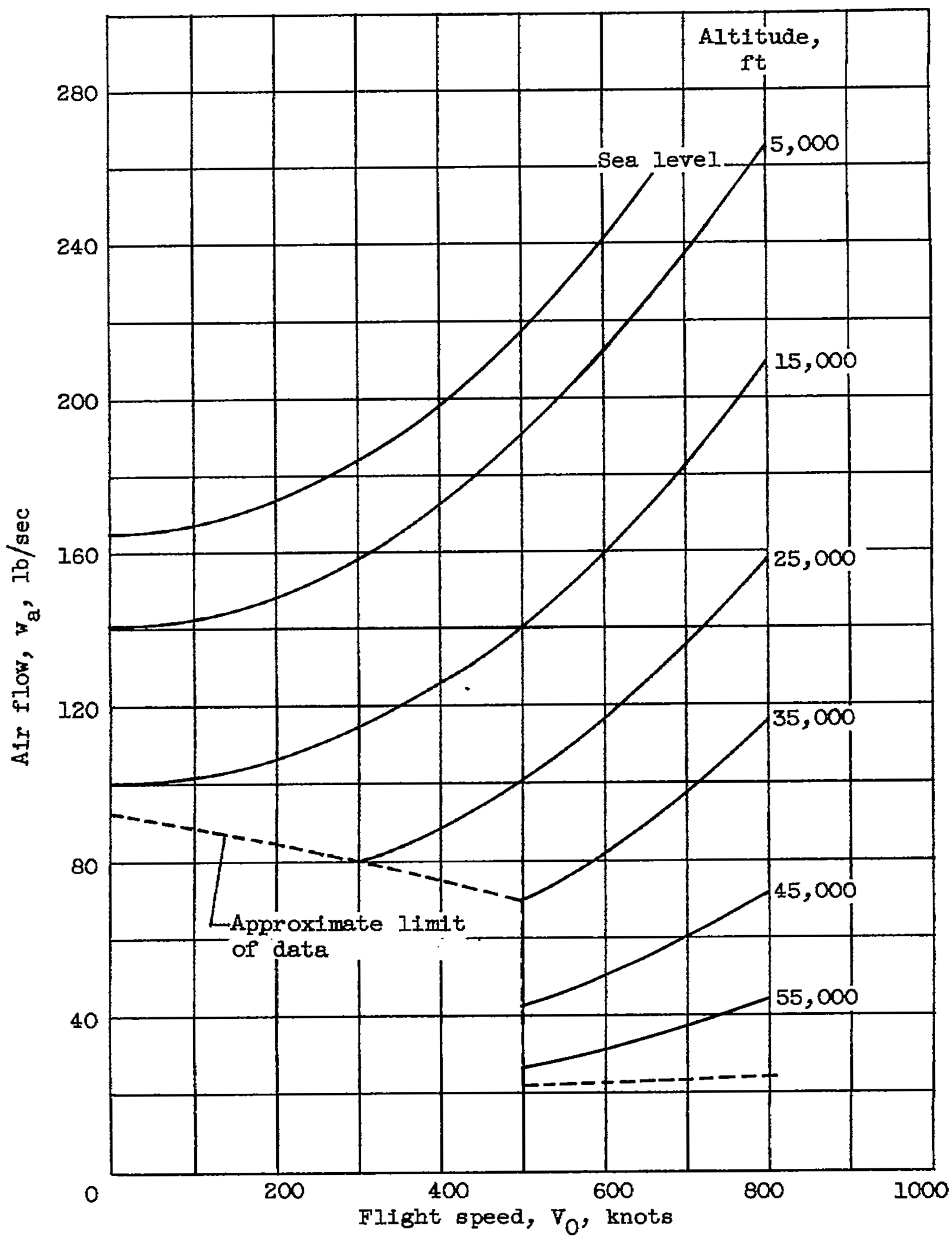
(a) Net thrust.

Figure 12. - Altitude performance. NACA standard atmosphere; 100-percent ram-pressure recovery at rated engine speed, 6175 rpm; rated turbine-outlet temperature, 1240° F.



(b) Fuel flow.

Figure 12. - Continued. Altitude performance. NACA standard atmosphere; 100-percent ram-pressure recovery at rated engine speed, 6175 rpm; rated turbine-outlet temperature, 1240° F.



(c) Air flow.

Figure 12. - Concluded. Altitude performance. NACA standard atmosphere; 100-percent ram-pressure recovery at rated engine speed, 6175 rpm; rated turbine-outlet temperature, 1240° F.

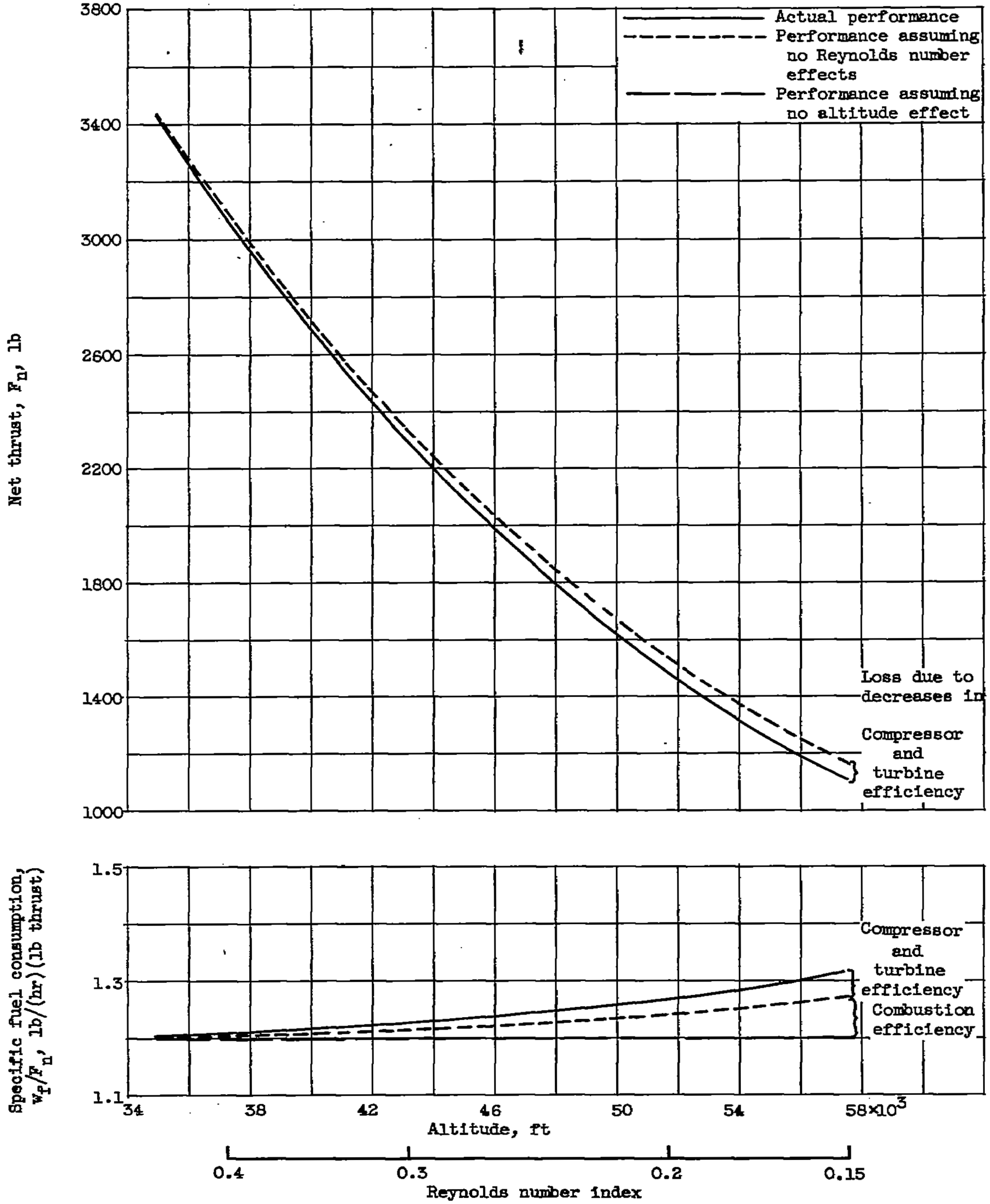


Figure 13. - Reynolds number effect on performance of J71-A-2 turbojet engine. Flight Mach number, 0.8; rated actual engine speed, 6175 rpm; rated turbine-outlet temperature, 1240° F; NACA standard atmosphere; 100-percent ram-pressure recovery.

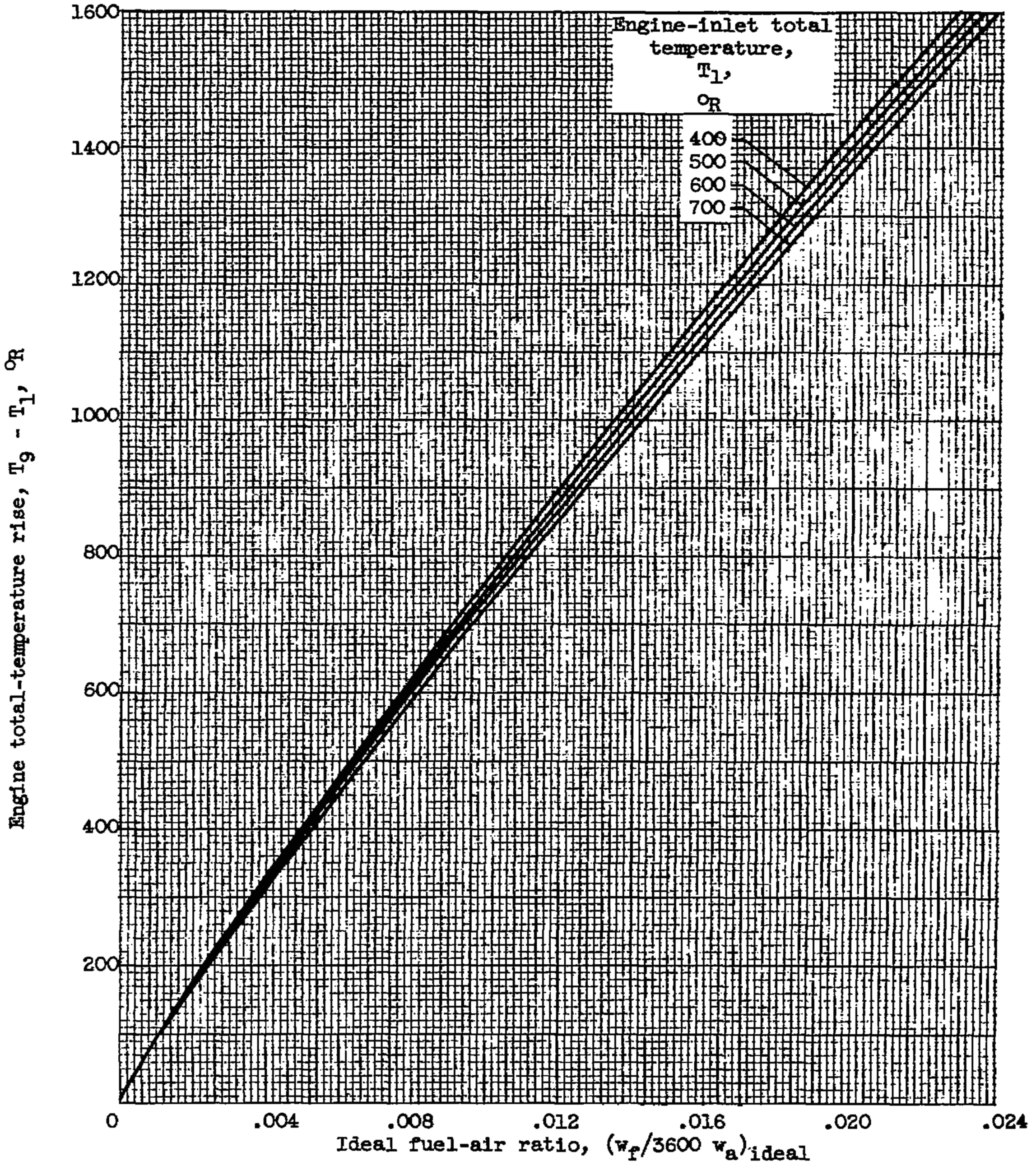


Figure 14. - Ideal fuel-air ratio of JP-4 fuel. Lower heating value, 18,700 Btu per pound; hydrogen-carbon ratio, 0.171.

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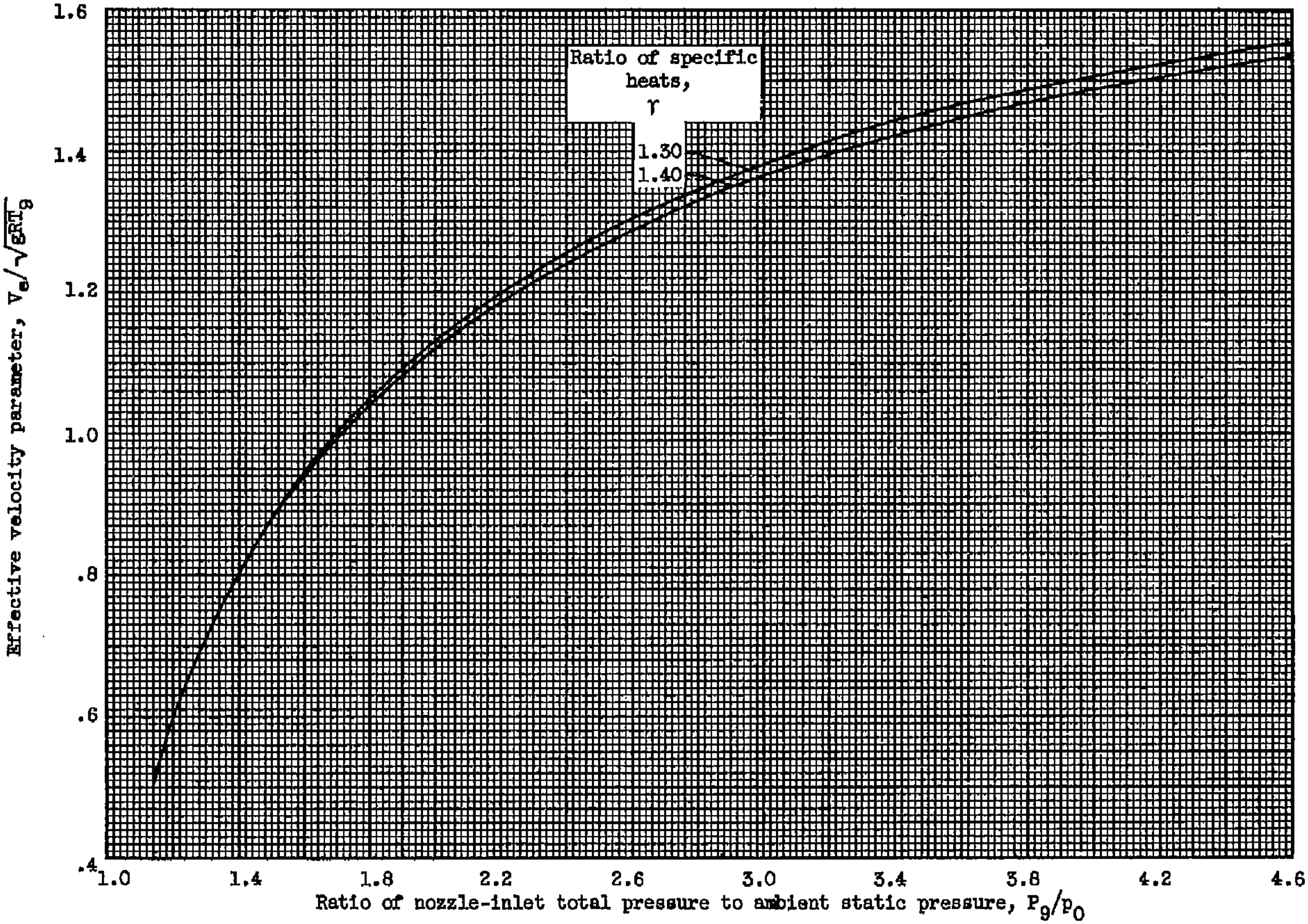

Figure 15. - Effective velocity parameter.

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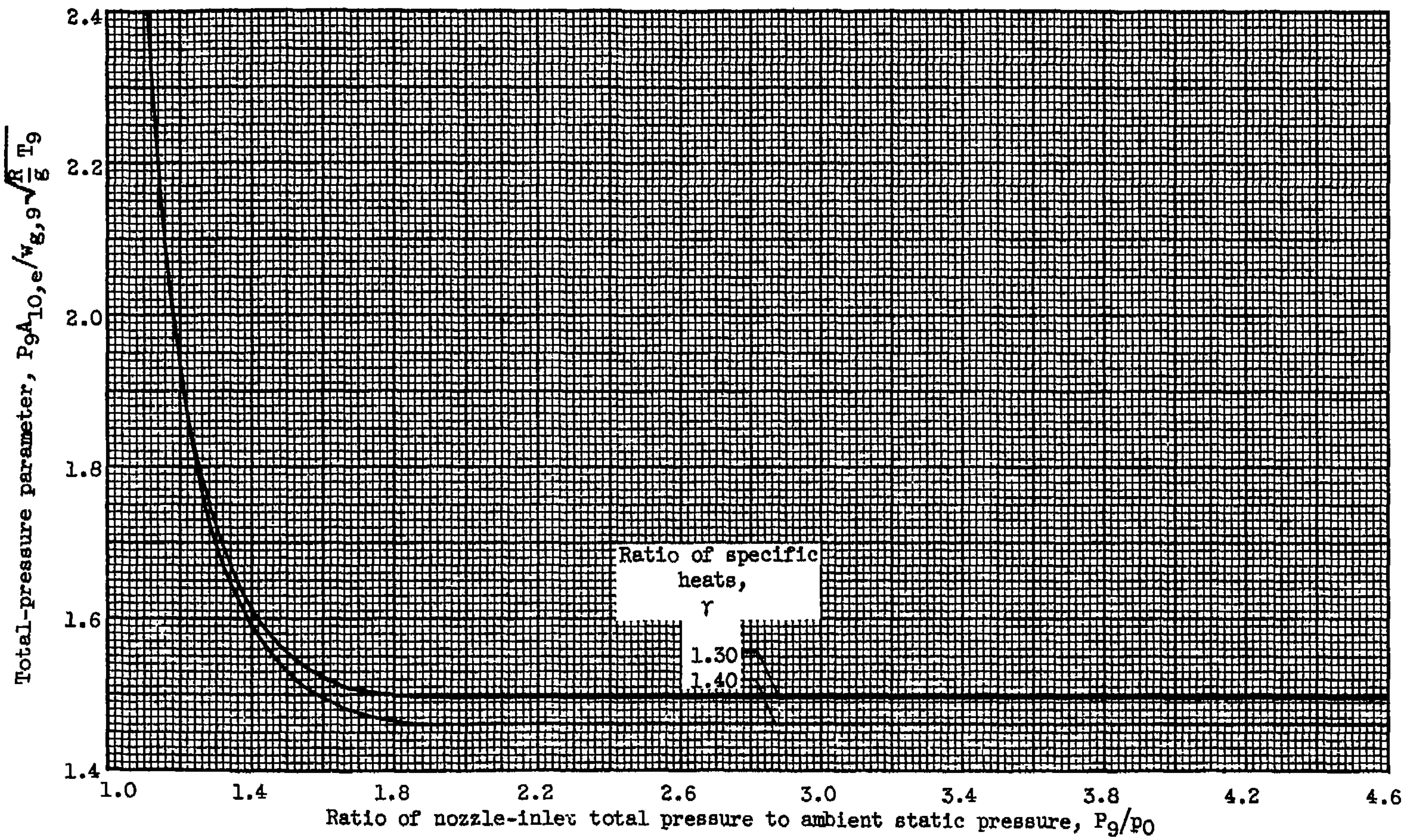

Figure 16. - Total-pressure parameter.

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